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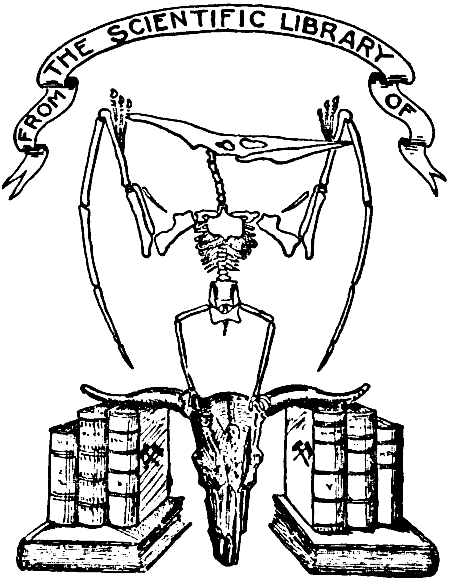
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"Recent Experiments in Sturgeon Hatching on the Delaware."

By Dr. Bashford Dean.

The region of the Delaware River near its mouth has long been the seat of an extensive sturgeon (*Acipenser sturio*) fishery. At Delaware City, Delaware, the great number of fish brought in daily to the wharfs during spawning time provide a locality especially favorable for experiments in artificial propagation. The studies by Prof. Ryder (published in the U. S. Fish Commission Bulletin) were here carried on in 1888, and during the present season this station was again selected for experiments to be made in behalf of the United States Commission of Fisheries.

At the time of the writer's visit the fishermen were bringing daily to the slaughtering wharfs from fifty to one hundred fish; and among these (May 16, 17, 18, 1893), a number of spawners were taken. There was thus abundant material for purposes of experiment. In the following paper the results of these test studies, in their bearing upon practical sturgeon culture, are briefly reviewed:

Fertilization.—The fertilization of the eggs, as known from former experiments,* is easily accomplished. The milt and roe even appear to retain their capability of fertilization under most unfavorable conditions. Ripe fish when brought into the docks had been out of water at least several hours; no precautions had been taken to insure their careful transportation, and they were usually near the point of death. In one case eggs were successfully fertilized which were taken from a fish apparently lifeless. The milt was found to remain active as long as a quarter of an hour after the fish had been slaughtered.

In the mode of fertilization, care in details appears to be needless. Eggs from ripe fish are readily fertilized, whether extruded by pressure or obtained by excision. In the latter case there is apparently no preference to be given to eggs from different ovarian regions. Excision is certainly the more speedy and convenient method. The eggs may be received with equal success in vessels, earthen, metal or wooden. Especial cleanliness is not vitally essential; in one case eggs were fertilized in an earthen bowl, from which a fixing solution of concentrated acetic-sublimate had been hastily rinsed.

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* In the United States those for example of Seth Green (New Hamburg, N. Y., 1875), Ryder (Del. City, 1888), Lotz (Ohio, F. C. Rep. 1890).

Milt may likewise be taken as well by excision as extrusion. In case the fish be not actually "ripe," sufficient milt for a fertilization may often be obtained in a pipette after repeated body pressure. Milt may be collected in vessels, clean, soiled or rusted, and will retain its activity (out of water) for at least six minutes. Obtained by excision the milt may be separated from the fragments of cut testes by coarsely straining through cloth. For convenience in handling, it was found that the milt might best be secured and retained in a long rubber bulbed pipette.

If untouched by water, the eggs remain capable of fertilization for several (5) minutes. Details in the mode of introducing the milt seem of little importance. No better results followed the introduction of milt directly from the living fish than of that strained from cut testes and retained several minutes in pipette. A few drops of milt were found to fertilize about two litres of eggs. In the experiments running water was in some cases added to the egg mass at the time of fertilization, in others as long as ten minutes afterwards; in all cases were results approximately the same. Within from twenty to thirty minutes the eggs have become viscid and "set." Under conditions of natural spawning, it seems probable that the eggs are fertilized at extrusion, since experiment failed to fertilize eggs that had been immersed in water about half a minute. This spawning condition is further attested by the scratches and abrasions noted on the abdomens of spent fish, both male and female.

Difficulties in sturgeon culture have usually been reduced to three—(1) those of obtaining ripe eggs and milt simultaneously, (2) of imperfect means of aëration of eggs, and (3) of inroads of fungus. It is evident that by careful experimental study the dangers of malaëration and fungus growth might be reduced, if not largely obviated. To these problems the attention of the writer was especially directed.

Difficulty of Aeration.—Sturgeon eggs have proven difficult to handle on account of their viscid character. Shortly after artificial fertilization the eggs stick together in a glue-like mass; this, speedily hardening, forms a compact egg mass, whose dense jelly-like matrix the culturist finds does not permit the inner and innermost eggs to be sufficiently aërated. Dying in consequence, these become the cause of the loss of the intimately connected surrounding although better aërated eggs.

On the natural spawning grounds this harmful condition does not, apparently, maintain. The eggs, fertilized and becoming viscid, appear to be drawn out into stringy clusters or ribbons, attaching at all points to submerged objects. Sticks, water weeds, fish nets and especially brush, spread over with a thin layer of sturgeon eggs, are well known to the fishermen. Egg-attached objects, it is generally noted, are found only in deeper, usually channel waters.

Favorable aëration, as suggested by natural conditions, seems accordingly to be insured by the disposition of the eggs in thin layers, and by a plentiful water supply.

To imitate these natural hatching conditions in a way practicable for large numbers of eggs is clearly the bourne of the culturist. To attain this, however, is not his easiest task. The eggs becoming viscid speedily must be attached to the hatching devices with the greatest promptness. The hatching trays must be prepared for immediate use, and the eggs must be spread over them simultaneously in a single layer. Otherwise all eggs becoming "set" at the same moment those that remain unspread must, in their clustered condition, be inevitably lost.

Aëration seems to be especially concerned with three cultural details—(1) the character of the egg trays, (2) the mode of egg attachment, and (3) the means of securing water circulation.

1. The shallow trays to which the eggs are affixed have, as far as the writer can find, been constructed either of fine metal gauze or of cheese cloth. In the present experiments the use of a coarse-meshed "mosquito netting" was found to give most satisfactory results. Of a tray bottom of this material the perforations are sufficiently large to admit an egg, but not so large as to permit it to pass through. A tray bottom thus prepared retains a single layer of eggs which may be aërated as conveniently on the under as on the upper side.

2. In former experiments the eggs, becoming viscid, appear to have been lifted from the water, spread upon the trays and retained thus until their attachment. In trials made at the suggestion of Mr. Pancost, of Delaware City, the eggs were spread upon immersed trays. Under water the eggs are easily handled, flowing smoothly over the netting tray, and by careful tapping of the tray frame may be made to assume a single layer. If placed on the tray ten minutes after fertilization they become firmly attached in about twenty minutes.

3. To assure the free circulation of water necessary to the hatching process, the egg trays are arranged in stout wooden cases, which float in the current or are sunk in deep water. Bottom and two sides of the cases covered with metal gauze permit a free passage of water current. In the present experiments the

floating hatching case differed from any of which the writer is aware in the following regards: It was nearly as deep as wide. By this means the hatching trays might be placed almost vertically, to thus take advantage of the water current and at the same time to economize space. As many as four trays to a case were successfully employed; these, held in position by cleats, were directed slightly downward to guard against deposits of sediment. The incoming current was directed against the under side of the tray.

The problems of aëration seem closely connected with those of fungus growth, as may be seen in the following paragraphs.

Inroads of Fish Fungus, Achlya.—The greatest difficulty encountered by Prof. Ryder in his experiments at Delaware City (1888) appeared to have been due to fungus growth. This was found to arise at various points of the hatching tray during the first forty-eight hours of hatching, and to gradually spread its velvety encasing over and stifle the entire egg mass. For success in hatching the means then suggested was water sterilization, the fungus spores to be removed by use of either filters or heat.

The effect upon fungus growth of more perfect aëration and increased salinity of water, however, had not been positively determined. And in the following experiment the writer aimed to reconsider these matters, hoping that favorable results might suggest a simpler and less costly means of evading fungus growth.

The results of Prof. Ryder had been obtained in a small fresh water pond emptying through the river bank directly into the Delaware; the hatching cases had been placed in a sluiceway through which water was constantly escaping; yet in spite of this current fungus inroads had here destroyed all but a few of the fertilized eggs. It was the plan of the writer to array a line of hatching cases from this shore point near the mark of low water out as far as the edge of the channel in deep water. By this means (the cases to contain eggs in every way similarly conditioned) the effects of difference of salinity, aëration and silt deposit upon fungus growth seemed most likely to be understood. Surface waters of mid stream, stronger in current, would naturally be better aërated and more devoid of silt than marginal waters. In channel, moreover, the water density was noted at 1.007 (sp. gr.).

The success of the experiment seems clearly to indicate the means that may be here taken to obtain practical results. The eggs in strong current, in salter and less silty waters, were practically exempt from attacks of fungus; those in marginal waters speedily perished (see accompanying table). It would in fact seem to the writer that the fungus is rather a consequent than a prime cause of egg destruction. That it is lacking under the natural conditions of sturgeon hatching is a fact not the most remarkable, and that it may be obviated in artificial processes by imitation of the natural hatching conditions seems the simplest and wisest plan of cultural procedure.

NUMBER OF CASE.	LOCATION.	PERCENTAGE OF EGGS DESTROYED BY FUNGUS.			
		2d Day.	3d Day.	4th Day.	5th Day.
I.	At outlet of fresh pond, as in experiments of Prof. Ryder,........	100	...	...	...
II.	At stake near line of low water,..	60	100	...	...
III.	At wharf sluice, a rod further out,.........	20	80	100	...
IV.	At wharf end, a rod further out,............	0	20	50	60
V.	In deep water in current at break water,......	0	5	5	5

It would appear from the above results that the problem of hatching sturgeon eggs is intimately conditioned by water current, by silt deposits, by salinity of water. To determine to what degree each of these factors is contributive to success would be granted most difficult. In the particular case of the common anadromous sturgeon (*A. sturio*) a slight degree of brackishness of water might be regarded as a favorable, if not a necesssary condition, were it not that the eggs of this species have been repeatedly hatched in water absolutely fresh. Current, on the other hand, could not have been alone an essential condition; since in the fresh sluice-way at Delaware City in the experiments of Prof. Ryder a circulation maintained stronger undoubtedly than in channel waters. Nor could the effect of silt be regarded as alone the unfavorable element; quantitatively in mid-stream—especially in sturgeon waters—an amount of sediment might be expected greater, doubtless, than of a neighboring spring-fed pond. Mode of temperature variations might, again, be looked upon as of problematic value. To what degree, then, is each of these conditions to be regarded as essential for success in sturgeon hatching? This problem, it cannot be doubted, is more troublesome in theory than in practice.

As to obtaining simultaneously the spawning fishes, male and female. In the event of extensive culture this difficulty is one that in the opinion of the writer could not be regarded as of serious weight. In a favorable locality each season brings a number of spawners to the wharfs of the fishermen, and with a regularity of occurrence that appears remarkable. In a letter to the writer Mr. Reuben Anderson, of Delaware City, well known as a most careful observer of the habits of the sturgeon, predicted *to a day* the appearance of spawners. He afterward stated that the "run" of fish,* though brief—often not longer than a single day—might, in his long experience, with every possibility be depended on.

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* A breeding habit of the sturgeon Mr. Anderson discussed with the writer seems for cultural purposes of the utmost significance The earliest fish in their passage up the stream spawn furthest from the river mouth, the next school in a locality not as distant, and the later fish in the lower stream regions. This zonal distribution in spawning seems attested by the character of fish as taken in their journey past a single shore front; the earliest are uniformly "cavaire fish" (i. e. of immature ovaries); later are taken "runners" (i. e., ripe fish); and at the close of the spawning season none but "slunkers" (i. e. those having spawned).

[Reprinted from the TRANS. OF THE N. Y. ACAD. OF SCIENCES, Vol. XIII.]

A NEW CLADODONT FROM THE OHIO WAVERLY
CLADOSELACHE* NEWBERRYI, N. SP.

BY BASHFORD DEAN.

(PLATE 1.)

Among the fossil sharks secured by Prof. Newberry, now in the possession of Columbia College, the writer finds an undescribed specimen which proves of considerable interest. It appears to have been collected by Rev. Dr. Kepler, near Linton, Ohio, about 1890, and when received together with other and better material was regarded by Dr. Newberry as an immature specimen of "*Cladodus*" (*Cladoselache**) *fyleri*. It is lacking in counterpart.

The fossil presents for examination the following parts: Visceral (?) aspect from near the tip of snout to hinder region of trunk (cf. in accompanying Fig. III.); a well preserved pectoral fin, muscle plates, the basal cartilages of a ventral fin, and in visceral region a well marked coprolite. The specimen measures in its widest part three, and in axial length thirteen inches. The length of the pectoral fin is two inches, its breadth one and one-half.

This fin, accordingly, is but about one-third (in linear measurement) the size of the pectoral of *Cladoselache fyleri*, but differing but slightly in its structures, the fossil might readily be assigned to this species. General proportions of the body, prove, however, to be widely unlike those of *fyleri*, and these together with the minor differences in fin structure might reasonably be taken as characteristic of a new species. The specific name the writer would dedicate to Dr. Newberry as the first describer of *Cladodonts*.

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* Cf. in current number of American Journal of Morphology the characters of this genus, as discussed by the writer, also, Trans. N. Y. Acad. of Sci. Vol. XII., p. 121, 1893.

Cladoselache newberryi proves of interest in its relation to Acanthodian, and in this regard will later be discussed.

It differs from *Cladoselache fyleri* in proportions, and in fin characters. In the former regard the fossil permits the following body distances to be taken for contrast: (a) length and breadth of pectoral; (b) distance of pectoral from centre of orbital ring; (c) distance of ventral from pectoral; and (d) body breadth. To establish this contrast the proportions of *fyleri* were first determined. These proportions, drawn to scale in the accompanying figures, I. and II., were taken in the first instance from a perfect example of this species whose structures have been figured in the current number of the Journal of Morphology. The tabular measurements, then compared with those taken from the type specimens of *fyleri*, were found to be remarkably uniform. Slight allowance, however, is doubtless to be made for distortion of body breadth. Axial percentages and fin proportions are constant.

In the following table the proportions are expressed:

CLADOSELACHE FYLERI.

Position and proportion of body parts expressed in percentage of axial length:

(Total length, axial, snout to tail tip,	100)
From snout to centre of orbit,	5
“ hind end of mandible,	12
“ origin of pectoral,	22
“ tip of pectoral (measured axially),	26
“ caudad margin of pectoral,	36
“ origin of ventral,	57
“ tip of ventral,	61
“ caudad margin of ventral,	67
“ anterior margin of caudal,	92
Span of pectorals,	35
“ ventrals,	14
Height of caudal,	24
Greatest apparent width of trunk,	15
Proximo-distad length of pectoral,	14
“ “ ventral,	4

In contrasting *newberryi* with *fyleri* the distance from orbit centre to origin of pectoral fin may conveniently be taken as a unit of proportional measurement. In terms of this unit of proportion the percentage distances of both species may first be determined.

The proportions of *newberryi*, when reduced, may then be expressed in the terms of the former species, thus:

	fyleri.	*newberryi.*
Distance from centre of orbit to origin of pectoral (unit of comparison),	1	1
Length of pectoral, measured axially	1	$\frac{3}{5}$
" " proximo-distad,	1	$\frac{3}{5}$
Distance from hinder margin of pectoral to origin of ventral,	1	$\frac{9}{5}$
Greatest apparent breadth of trunk,	1	1

It will accordingly be seen that Cladoselache newberryi was proportioned not unlike the recent eel-like frilled shark, Chlamydoselache. It differed from other known Cladodonts in the smaller size of the pectoral fins and the greater interval between the paired fins (cf. Fig. III.). The snout, only in part preserved in the fossil, seems to have been longer than that of *fyleri*. The head at eye region appears notably broad.

In addition to these differences in proportions, *newberryi* is readily distinguished by the structure of its pectoral fin (see Fig. IV.). Although the fin rays agree substantially in number and relative sizes, their mode of arrangement is clearly different from that of *fyleri;* the rays are notably compacted antero-posteriorly, and have lost to some degree the graceful curve in their placement. They have thus become set rigidly almost at right angles to the fish's axis, and in their straightness and compactness, their row of graded sizes appears clearly suggestive of the fin spine of Acanthodian. The entire fin is narrower and more acutely pointed than that of *fyleri*.

Circum orbital plates, although not perfectly preserved in the fossil, are relatively larger than those of *fyleri*, and appear less numerous, doubtful in this character perhaps on account of imperfect preservation (Fig. VIII.).

The basalia of the left ventral fin are imperfectly preserved (Fig. V.). Their number and position, however, vary but little from the conditions of *fyleri*. Six basalia are to be determined.

Near by, anteriorly, is the impression of what must be regarded as a coprolite, while still further forward (Fig. III., A) is an entire coprolite well preserved. The latter (Fig. VII.) is especially interesting since it furnishes a cast of the intestinal wall and gives definite evidence as to the presence of a spiral valve. This structure, accordingly, maintained in the generalized Cladodont; and that the intestinal septa were here low and numerous is most significant phylogenetically. Its condition in this form, as the nearest known ancestor of Selachians, would, moreover, give an additional reason for emphasizing the most ancient origin of Dipnoan, Teleostome, and even Chimaeroid. The coprolite seems remarkably small in comparison with the total body width of the specimen; its striæ are six in number, and are somewhat irregularly disposed, the hindmost one notably furthest from its fellows.

Myomeres are well shown in the fossil in the regions indicated (Fig. III., C. C. C.); a figure here given illustrates their coarse longitudinal striation (Fig. VI.).

The especial interest which Cladoselache newberryi presents is in its Acanthodian features. It advances clearly from the known Cladodont forms along the line of specialization. It is in the first place a form of smaller size, of but somewhat more than half the length of *fyleri* and less than one-third that of *kepleri*. Its pectoral fin is narrower and more acutely pointed, better adapted to a more specialized function; its radials becoming straighter and more compressed are strongly suggestive of the elements of the fin spine of Parexus. Enlargement in size of the circum-orbital plates (with probable decrease in their number) is finally to be noted in its Acanthodian bearing.

Mr. Arthur Hollick made the following remarks on the paper:

One part of Dr. Dean's investigations throw an unexpected flood of light upon a matter in which I am much interested, and in regard to which there has always been a great diversity of opinion.

I refer to certain peculiar screw-like fossils which have been described from time to time, both from this country and abroad, under the names *Spiraxis*, *Spirangium*, *Palæoxyris*, *Palæo bromelia*, *Fayolia*, etc. It may, perhaps, be remembered that Dr. Newberry described two species from the Chemung sandstone, under the names *Spiraxis major* and *Spiraxis Randalli*, in the Annals of the Academy (Vol. III. (1855) 217–220, Pl. XVIII.). His descriptions and figures and the type specimens upon which they were founded are here for comparison, and we can hardly doubt that they are identical with the coprolite figured by Dr. Dean from the intestine of the shark.

These fossils have been referred by different investigators to *Xyris*, *Bromelia*, *Chara*, stems of algæ, etc. Dr. Newberry did not venture any positive opinion as to their affinities, but mentioned incidentally their possible reference to algæ or sponges.

Upon examining Dr. Dean's drawing I was at once struck by the remarkable likeness between the coprolite and *Spiraxis*, and comparison of the specimens satisfied us both they represented similar fossils.

Of course we can not say that all the fossils mentioned may be referred to the same source, but in regard to the specimens from the Chemung there can hardly be any doubt, and as all or nearly all the others are likewise from rocks representing geological horizons in which sharks were plentiful, we may at least assume the probability of a similar origin for all. The matter, however, was only called to my attention two days ago, so that there has been no opportunity for anything like careful research, and we must leave any extended dissertation upon the subject until some future time, merely placing the fact of the comparison upon record.

EXPLANATION OF FIGURES.

FIG. I. *Cladoselache fyleri*, Newb. A restoration drawn to scale according to measurements of type specimens (x¼). The number of gill clefts, of which seven are figured, is here at the best approximate. Eight or nine may well have been present. The horizontal keel at the base of the caudal is represented by shading. The dorsal (?) fin is not definitely known.

FIG. II. *C. fyleri*, Newb. Ventral aspect. The condition of the gill clefts ventrally has not been determined; there is reason to believe that the anterior isthmus-flap was considerably larger than here indicated, and like that of the recent *Chlamydoselache*, may have extended caudad so as to protect the hinder clefts. The body width, if allowance be made for distortion in fossilization, is perhaps more accurately expressed by the maginal dotted lines. In ventral aspect the horizontal caudal keel is indicated by shading.

FIG. III. *C. newberryi*, n. s. Ventral aspect. The right pectoral fin, together with outlines of ventrals, has been added. The left mandibular ramus and the hinder margin of the isthmus-flap are visible in the fossil. (x¼).

A. Coprolite (cf. Fig. VII.).
B. Basalia of left ventral (cf. Fig. V.).
C. Myomeres (cf. Fig. VI.).

FIG IV. *C. newberryi*. Pectoral fin (x1). Radialia straighter and more compressed antero-posteriorally than in *fyleri*: fin's body-length shorter.

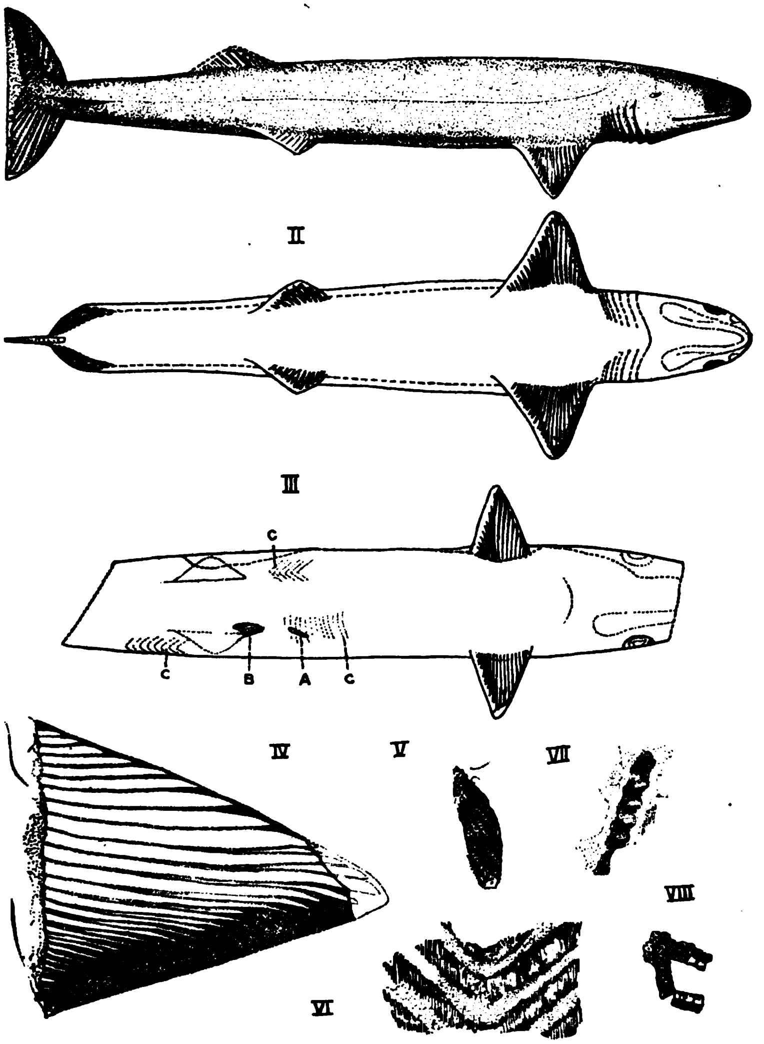
FIG. V. *C. newberryi*. Basalia of ventral fin. These, although poorly preserved in the present specimen, agree in position with similar structures in *fyleri*.

FIG. VI. *C. newberryi*. Myomeres (x1).

FIG. VII. *C. newberryi*. Coprolite (x1) showing well marked impression of spiral valve.

FIG. VIII. *C. newberryi*. Circum-orbital derm plates (x1).

Professor J. F. Kemp exhibited a series of thin sections of typical rocks by the lantern with polarized light.



CLADOSELACHE NEWBERRYI DEAN.

With the Compliments

[Reprinted from the TRANSACTIONS N. Y. ACAD. SCI. May 11, 1896.]

ON THE VERTEBRAL COLUMN, FINS AND VENTRAL ARMORING OF DINICHTHYS.

BY BASHFORD DEAN,

Department of Zoölogy, Columbia University.

Hitherto our definite knowledge of this most interesting of American Arthrodiran fishes has been limited to the structures of the anterior body parts—the jaws and the plates of the head, "shoulder" and abdomen. It was upon these characters, as described in several species, that the inference had been made that Dinichthys was closely akin to the European Coccosteus.

But any satisfactory comparison of the relations of these kindred Arthrodirans could, it is evident, only be made when the endoskeletal and appendicular structures of Dinichthys should be discovered. For the vertebral column, girdles and fin structures are certainly more constant as landmarks in the differentiation of genera than are the outlines or tuberculations of dermal or dental plates.

It is now accordingly of general interest that a fossil has been found which throws unquestionable light upon the structures of the backbone and fin bases of Dinichthys. This unique specimen* was discovered in the vicinity of Berea, Ohio, by Dr. William Clark, to whose zealous studies, indeed, a large part of our knowledge of American Arthrodirans has been due. It was brought to my attention in 1894 by Dr. Clark, and was subsequently forwarded to the Zoölogical Laboratory of Columbia University for renewed study. A further courtesy of its discoverer has now enabled me to present the following description:

The fossil is contained in an oblong shaly concretion, somewhat coarser in texture—sandstone-like and lighter in color—than those commonly found in the Cleveland shales. It measures about 25 cm., occupying almost the entire length of the concretion. The appearance of the fossil is shown in the accompanying figure (Plate VII.). This, it should be explained, was prepared from a tracing of the structures displayed on the right half of the concretion, and to this drawing were added from the counterpart the posterior ventral plates, R P V and L P V, a coprolite, C, a portion of the "ventral fin," V F, and the two plates of unknown position, U. These additional structures are accordingly shown in their normal position in the fossil, but the plates R P V and L P V should be understood to overlie, not underlie, the ventro-median plate, V M.

As to the identification of the fossil as Dinichthys, a comparison of the plates, VM, RPV, LPV and AV, with those of the ventral armoring of Dinichthys as figured by Newberry† and Wright‡ leaves little doubt that these structures belonged to this genus. The plates are relatively thinner, however, than those of the types of D. terrelli and D. intermedius, but the writer finds by an examination of the plates of the type D. gouldi, Newb., preserved in the Geological Museum of Columbia, that the present specimen may be assigned almost definitely to this species.

The fossil presents for examination the following structures:

(A). Plates of the ventral armoring, AV, VM, LPV, RPV, U (?).

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*The type is preserved in the Clark collection.

†Newberry, Palæozoic Fishes of North America, U. S. Geol. Surv. Monogr. XVI.

‡Wright, The Ventral Armor of Dinichthys, Am. Geol. Vol. XIV., Nov., 1894.

(B). Notochordal area and vertebral arches, NC. NA, HA, HS.

(C). Supporting elements of the dorsal and of a pelvic fin, DF, VF, VG.

(*A*). VENTRAL ARMORING.

There is little difficulty in identifying the typical plates of the ventral armoring, and in the accompanying figure, Pl. VIII., Fig. 2, these have been arranged in approximately their natural relations.

Of the *Anterior Ventrals* the fossil exhibits but a single plate, the left, Pl. VII., AV; this is shown in visceral aspect, its anterior margin broken and weathered. Its lateral margin, like that of Coccosteus, as described by Traquair,* and like that of Dinichthys terrelli, as recently shown by Wright (op. cit.) is the thicker; and along this margin, which, by the by, is relatively wider and less incurved than in D. terrelli, pass well-marked parallel striæ. The opposing margin of the plate is thinner, and shows little trace of encircling striæ, although the weathering of the surface may possibly account for their absence. Vascular canals (Haversian), rendered more conspicuous by the weathered surface, pass directly into the plate in its antero-lateral region; from this center they diverge radially, and become most conspicuous as open furrows in the thinner peripheral parts. The plate's elongated candal end seems especially thin where it overlaps the left posterior ventral (Cf. Pl. VIII., Fig. 2, LPV).

The *Posterior Ventrals* are both shown in the fossil, Pl. VII., R P V, L P V. They are seen in visceral aspect, and appear to occupy very nearly their normal relations. Portions of these plates have been lost, but their structure is admirably preserved. The margins of the visceral surface are marked by concentric striæ, which as in all the derm plates of Arthrodirans may be regarded as rings of growth. The focus of the vascular canals is prominent in the middle region of the plate, their radiating tubules becoming most conspicuous peripherally. The middle region of the left posterior ventral has been detached, but in such a way that a portion of its outer (surface) layer has been left in position. This fragment demonstrates clearly that the surface of the ventral armor in this, if not in every species of Dinichthys, was tuberclated. These tuberculations are fine, closely arranged, and project little above the surface; they form an encrusting superficial layer and, as the specimen indicates, separate readily from the underlying table of the plate. On this account it is possible that the dermal plates of Dinichthys terrelli, intermedius and curtus have always appeared to have been lacking in shagreen-like structures, thus giving ground for the belief that these plates were deeply embedded in the ventral integument.

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* Traquair, Ann. Mag. Nat. Hist. [6] Vol. V., (1890), pp. 125-136.

The *Ventro-Median* plate, Pl. VII., VM, has been retained in a fair degree of preservation. Like the neighboring plates, it exhibits its visceral aspect, and has been but little displaced. Parallel to its margins are well-marked striæ, and a series of straight vascular tubules converge toward its center. The plate's anterior end terminates in an enlarged, flat, rounded area, which appears to be the homologue of a separate plate in Coccosteus, the "anterior median ventral" of Traquair. In Dinichthys, however, this element is relatively much smaller in size. In the present specimen its surface has been greatly weathered.

Two additional dermal plates are shown in the fossil, Pl. VII., U. They appear to represent a pair of plates hitherto undescribed in Dinichthys. Of their relations little is suggested, although it is possible that they represent the antero-lateral plates of the shoulder armoring of Coccosteus. In the neighborhood of these plates the fossil has retained a large pale-colored mass, amorphous, ragged in fracture, which in character and position may well represent a coprolite. It is lacking, however, in fish fragments, and, if a coprolite, it affords no evidence of the presence in Dinichthys of an intestinal spiral valve.

Comparison of the ventral armor of Dinichthys gouldi with that of D. terrelli, as described by Wright, gives evidence that the conditions in the smaller species were by far the more generalized. (cf. Pl. VIII., Figs. 2 and 3.)

Thus, in D. gouldi, Pl. VIII., Fig. 2.

1. The anterior and posterior ventro-lateral plates correspond closely to each other in size.
2. The anterior ventro-laterals were simple oblong plates, comparatively uniform in thickness, and straight margined, *i. e.*, not crescent-shaped as in D. terrelli.
3. The relation of the anterior ventro-laterals to the posterior ventro-laterals was a simple one, the former overlapping the latter broadly and apparently loosely; there is no evidence that the overlapping portion of the anterior plates were fitted into an insunken area in the hinder plates.
4. The posterior ventro-laterals were simple oblong plates; their hinder median margins overlapping (the right possibly overlapping the left, unlike in Coccosteus), but showing no trace of the peg-and-socket suture by which they are united in D. terrelli.
5. The outer surface of the plates (posterior ventro-laterals,

and probably the rest as well) was tuberculate as in the earliest Dipnoans and Teleostomes.

And it is further evident that the ventral armoring of D. gouldi does not differ widely from that of Coccosteus. (cf. Pl. VIII., Figs. 1 and 2.)

(*B.*) NOTOCHORDAL AREA AND VERTEBRAL ARCHES.

The space formerly occupied by the notochord is clearly apparent in the present fossil, Pl. VII., NC. And an idea may even be obtained of the notochord's relative thickness, as it passed tailward from the region of the ventral armoring in the broad space margined on either side by the remains of vertebral arches. As nearly as the present writer can determine the proportional thickness of the notochord in Dinichthys is not widely different from that in Coccosteus, although, perhaps, slightly thicker in the former type. In neither form have any traces been found of vertebral centra.

The vertebral arches, as shown in the present fossil, Pl. VII., NA, HA, have been imperfectly preserved. The following notes regarding them may, however, be safely made: They were as numerous, relatively, as in Coccosteus; they show a similar regional differentiation, and appear to be similar in structural regards. On the other hand, they differ from the conditions in Coccosteus in being shorter and more uniform in length. Their substance, too, appears to have been frailer, and judging from the structures shown in several cases, it seems probable that these arches could not have been widely different from those of Ceratodus, *i. e.*, cartilaginous internally, the superficial layers encrusted with lime. Under these conditions the hæmal and neural structures would naturally be subject to distortion during fossilization.

The neural arches seem to have tapered distally into a neural spine. The fossil shows no evidence that this may originally have been a separate element, nor does it show that the neural arch had ever appended to it a more distal element. The hæmal arches, on the other hand, seem to have terminated bluntly and to have been capped by a separate spine-shaped element (hæmal spine?) as seen, for example, at HS in Pl. VII. It must be admitted, however, that this jointed appearance may have been due to artefact. If a normal character, the separation of the naemal spine from the arches becomes an important diagnostic character, separating Dinichthys from Coccosteus.

(*C*). SUPPORTING ELEMENTS OF THE DORSAL AND OF THE PELVIC FIN.

The position of the basal support of the dorsal fin may be outlined in the fossil, Pl. VII., DF, although they are imperfectly preserved. In number they correspond closely to those of Coccosteus, but in other regards they appear to have been widely different; they are thus smaller and slenderer, and the elements of their proximal row, although very imperfectly shown, seem to have differed considerably from the neighboring distal elements. It is also noteworthy that the outer tips of the distal elements appear to have been the more densely calcified, so that indeed these tips could remain after the remaining portion of the element had disintegrated. Several of these separated distal ends may be noted in the fossil. The evidence now presented is sufficient to demonstrate that the dorsal fin of Dinichthys was relatively in the same region as in Coccosteus, but that it was smaller and more delicate, the latter character directly opposed to what might have been inferred on *a priori* grounds.

The pelvic girdle and the basal supports of the ventral fin are shown in the fossil, at VG and VF, Pl. VII. Their preservation is, however, so imperfect that nothing definite can be determined about them; indeed were it not that this portion of the fossil corresponds so closely in position and outline to the structures of the ventral fin and hip girdle in Coccosteus, one could hardly be justified in atttempting an identification. The writer is inclined to believe that the apparently separate elements at VF. are in reality not the basalia of the ventral fins, but artificially separated portions of the distal part of the pelvic girdle.

Fin structures in Dinichthys (terrelli) have already been described by Prof. Newberry, and figured by him in his Palæozoic Fishes (Monograph XVI, U. S. Geological Survey, Pl. VII.). His specimens, however, had been sent him without their matrix, and he could not therefore determine their exact position. They had been received from Ohio from Mr. J. Terrell, who had several times found them associated with the bones and plates of D. terrelli. These "ossified fin rays," as far as Dr. Newberry could judge from a single detached group of them, and from several fragmentary elements, were then believed to represent in part the base of the dorsal fin. The structures of the present specimens are certainly not adverse to this view of Dr. Newberry. But a reëxamination of the types by the present writer leads to the belief that they may well have been exernal fin structures.

They certainly do not correspond to the basalia of the dorsal fin shown in the present material, although they may have represented the external rays. It is possible that they may prove to have been caudal structures.

The additions to a knowledge of the structures of Dinichthys as given in the present paper, may be summarized as follows:

I. Presence of notochordal axial skeleton, of dorsal fin and of pelvic girdle, similar to those in Coccosteus.

II. Presence of an hitherto undescribed pair of dermal plates.

III. Evidence that a pair (and probably, therefore, all) of the plates of the ventral armoring were surface plates.

A contrast of the ventral armoring of Dinichthys gouldi with the corresponding structures in D. terrelli and in Coccosteus (cf. Pl. VIII., Figs. 1, 2 and 3), leads the present writer to believe that the conditions in Coccosteus are most nearly those of the common ancestor of these three forms. And that in D. gouldi are present more generalized conditions than in the larger species. Thus in Coccosteus the plastron is composed of separate dermal plates, more or less rhomboidal in outline, and differing little from each other in size. In Dinichthys, on the other hand, these plates differ more widely from each other in size and outline, the median plates—median ventral and anterior median ventral—no longer broadly lozenge-shaped and separate, are now reduced to a single narrow lanceolate element. In D. gouldi the plates of the plastron overlap as in Coccosteus; in D. terrelli they become more widely unlike each other and are fixed together with definite sutures.

May 12, 1896.

PLATE II.

Dinichthys gouldi, Newberry ; × $\frac{3}{4}$. A specimen showing vertebral axis, ventral armoring and bases of dorsal and of ventral fin. From the collection of Dr. William Clark, Berea, Ohio. A V, Anterior ventral. C, Coprolite. D F, Basalia of dorsal fin. H A, Haemal arch. H S, Haemal spine. L P V, Left posterior ventral. N A, Neural arch. N C, Notochord. R P V, Right posterior ventral. U, Plates of unknown position (perhaps posterior laterals (Traquair) of Coccosteus). V F, Basalia of ventral fin (?). V G, Pelvic girdle. V M, Ventro-median.

(The plates L P V, R P V, and portions of C, U and V F were attached to the right half of the concretion. They are here shown as if attached to the opposite half of the concretion: they thus appear in their actual position, but in reversed aspects.)

(The plate is repeated from Vol. XV., Plate VII.)

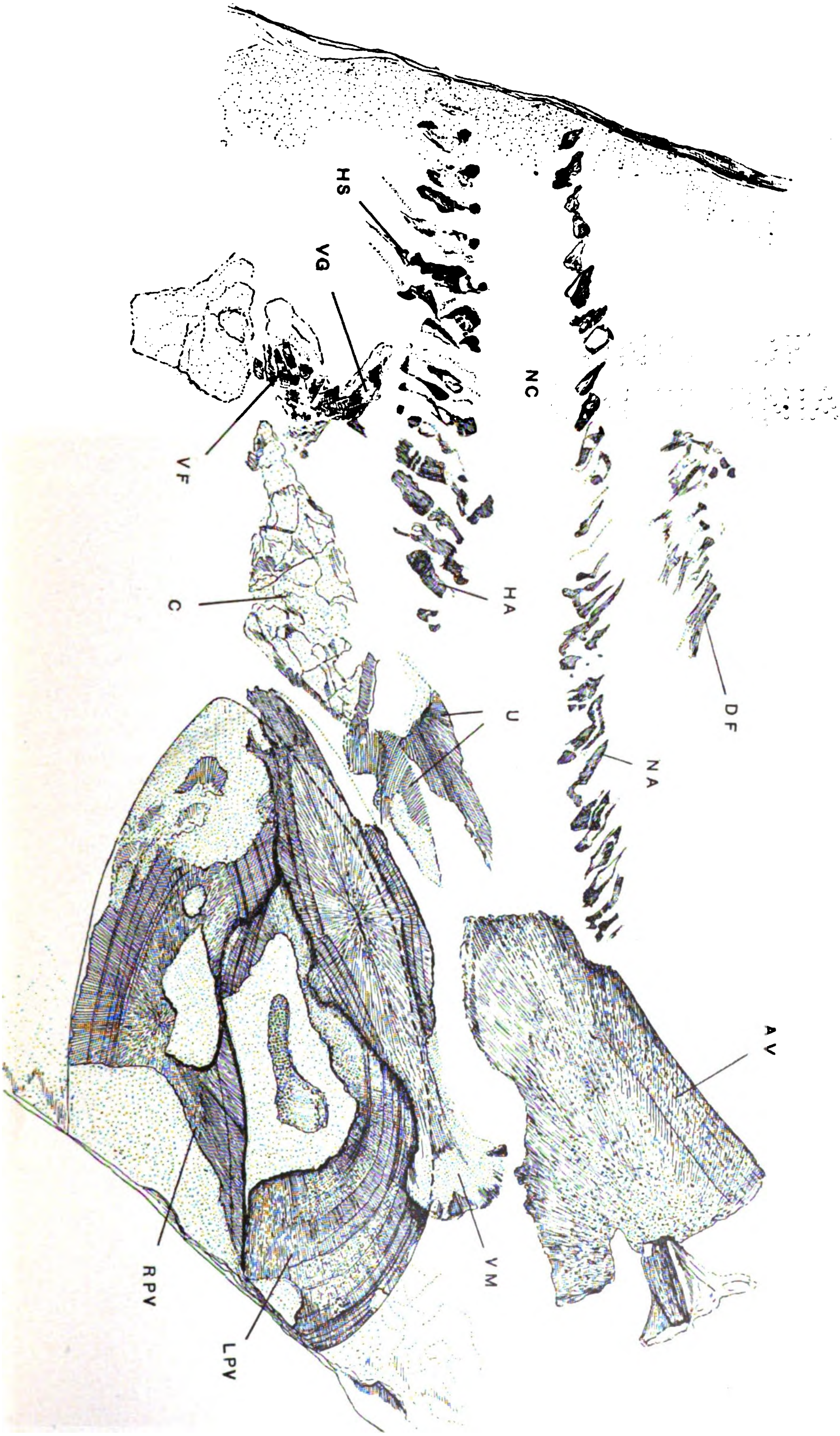
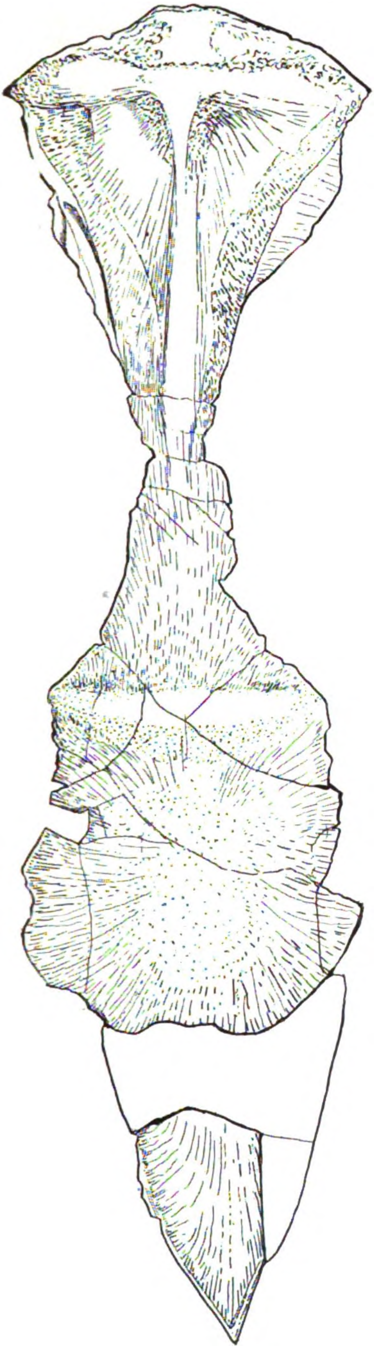

HS
VG
VF
NC
C
HA
U
DF
NA
AV
VM
RPV
LPV

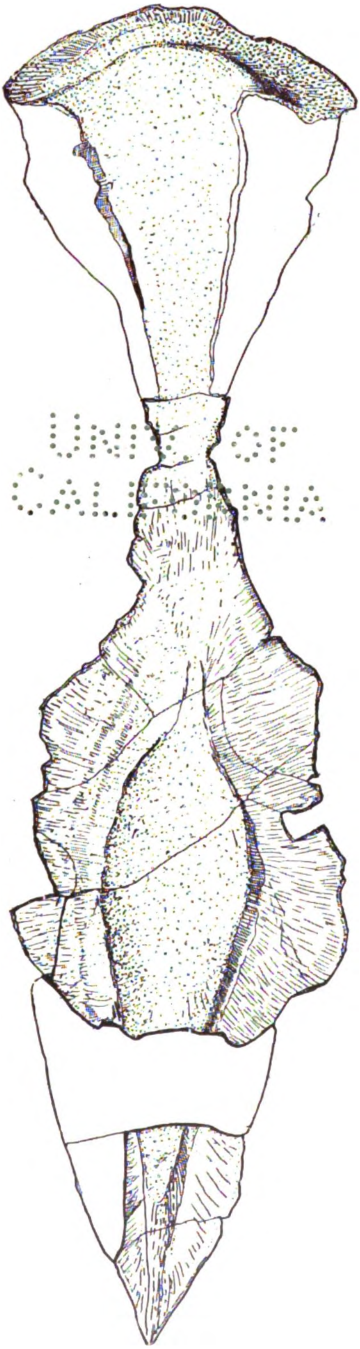
PLATE III.

Ventro-median plate of *Dinichthys terrelli*, Newb. x about ⅓. From the Terrell Collection in Columbia University Museum.

Shown in both aspects, the ventral (ectal) being at the right.

V. p 59.





UNIV. OF CALIFORNIA

6

ON A NEW SPECIES OF EDESTUS, *E. LECONTEI*, FROM NEVADA.

By **Bashford Dean**,

Department of Zoölogy, Columbia University.

[From Transactions New York Academy of Sciences, Vol. XVI., pp. 61–69 January 25, 1897.]

[Reprinted from TRANSACTIONS N. Y. ACAD. SCI., Vol. XVI., January 25, 1897.]

ON A NEW SPECIES OF EDESTUS, *E. LECONTEI*, FROM NEVADA.

BY BASHFORD DEAN.

Department of Zoölogy, Columbia University.

Dr. John C. Merriam of the University of California brought to the attention of the present writer during a recent visit to Berkeley a unique and undescribed species of Edestus. This had been collected, together with several other fossils, in the mining region within a mile of Eureka, Nevada. The note as to its exact locality had unfortunately been lost, but from the well described stratigraphy * of this region Dr. Merriam had known that the fossil as either Devonian or Carboniferous, believing it, however, Carboniferous since all the species of Edestus hitherto described are known to be of this age. In any event the discovery of Edestus in Nevada extends notably the range of this genus, since in this country it has hitherto occurred only within the limits of the Mississippi coal field, in Arkansas, Indiana and Illinois. It is now seen to have occurred west of the Rocky Mountains, and in this direction it next appears in the Carboniferous of Australia.

The present specimen differs in a somewhat marked way from kindred species. And it proves of especial interest as affording a number of morphological notes concerning this, possesibly the most puzzling fossil of our North American fishes. Through the courtesy of Dr. Merriam the writer is now permitted to figure and describe it. The new species has been named in honor of Professor Joseph LeConte of the University of California, in recognition of the long services of this distinguished geologist.

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* *Geology of the Eureka District.* Arnold Hayes' monograph. Mon. Geol. Surv. xx. Also *Palæontology.* C. D. Walcott. *Ibid.* viii.

EDESTUS LECONTEI, n. s.

Type in the Palæontological Cabinet of the University of California.

The fossil is shown in about its natural size in the accompanying figure, Pl. IV, Fig. 1. Its matrix, a carboniferous shale, resembles closely that of *Edestus heinrichsii* or of *E. minor*—light gray in color, hard and brittle. The spine is not preserved as perfectly as in specimens of other species which the writer has examined. Its surface bears evidence of having been somewhat weathered prior to fossilization; the enamel of the large marginal denticles appears altered, and it is only at favorable points that the segmented nature of the spine may be determined. The following characters may be described: The base (shaft) of the spine is broad at one end and tapers gradually toward the other. The former may therefore be regarded as the proximal end. The distal termination has not been preserved, but judging from contours this region of the spine may well have measured half an inch longer. Where the tip has been broken off abruptly the spine is triangular in section, Pl. IV, Fig. I. A, and appears to have been relatively stout—for the proximal end was notably flattened and might be represented in transverse section by a long ellipse. Along the dorsal (convex) rim of the spine are arranged seventeen large denticles; those of the proximal region are tall and acutely pointed; those of the distal end wide and short. The latter bear evidence of having had rounded ends, although in these portions they have not been perfectly preserved. Between these two extreme types appear transitional forms causing the line of denticles to present a graded series. Each of these elements is flattened in the plane of the sides of the shaft of the spine, precisely as in *E. davisii*, and presents a cutting edge on anterior and posterior rims. Along these cutting edges of the large or primary denticles a row of small secondary denticles has not been definitely determined in the present specimen, owing possibly to imperfect preservation. It should, however, be noted that at several points on the fore most primary denticles a peculiarly roughened margin might perhaps be interpreted as a series of minute secondary denticles. The segmented character of the shaft in *E. lecontei* is by no means clearly marked. In the proximal region the basal segments may be determined, but, as shown in the present figure, they are certainly inconspicuous. Traces of them disappear entirely in the hinder region of the shaft.

The relation of E. lecontei, to other species of Edestus.

The structural characters of *Edestus lecontei* differ notably from those of other species. The number of its primary marginal denticles is greater. In this respect, however, an accurate comparison cannot be made, since all of the specimens of which have been described in other species of Edestus are possibly imperfect—*i. e.*, lacking in proximal or terminal elements. Of those described, the spine of *E. davisii*, as figured by Mr. Henry Woodward, is probably the most perfect, having fourteen primary marginal denticles. The greatest number possessed by the other species, *E. minor*, *E. heinrichsii*, and *E. giganteus* does not, as far as the writer is aware, exceed seven. In the case of *E. vorax*, no greater number than four appears to be known, judging from the figure of Prof. Newberry [*] which was doubtless taken from the best specimen in the collection of Dr. Leidy. In the latter case it must, however, be noted that the spine bears every evidence of having been not widely unlike that of *E. heinrichsii*. Further differences of *E. lecontei* include: the tapering character of the spine, the antero-posterior differences in the primary denticles, the possible absence of secondary denticles, and finally the obliteration of the segmental elements of the spine-base. In all of these regards this spine is widely unlike all other members of its genus.

An interesting comparison of the characters of five species of Edestus may be made by reference to the accompanying figures, Pl. V, Figs. 2–6. For in these the spines have been reduced to the same size, represented in relatively the same aspect, and arranged with a view of suggesting the lines of their relationship. The writer has thus placed the form, *E. heinrichsii*, at the top, as presenting the simplest type of Edestus, and has ranked the remaining forms in the following order: *E. giganteus*, *E. minor*, *E. davisii*, *E. lecontei*, the last as the most highly specialized.[†]

A review of the structural features of these forms has been attempted in the table on the following page.

The morphological relations of the spines of Edestus.

In the foregoing pages the writer has assumed that *Edestus* is to be regarded as an elasmobranchian spine. As far as the above comparison is concerned, however, this determination need not be strictly adhered to, for from the morphology of vertebrate dermal structures the arrangement of the forms represented by the five species might still hold good—*i. e.*, the position *E. heinrichsii* as the most generalized form, and of *E. lecontei* as

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[*] J. S. Newberry. "On the Structure and Relations of *Edestus*, with a Description of a Gigantic New Species." Annals N. Y. Acad. of Sci. Vol. IV, No. 4, 1888. Pp. 10, pls. 8.

[†] *E. vorax* has appeared too fragmentary to be admitted in this comparison: its structures would probably place it between the types *E. giganteus* and *E. minor*.

A COMPARISON OF THE STRUCTURAL FEATURES OF FIVE SPECIES OF EDESTUS.

	E. heinrichsii.	*E. giganteus.*	*E. minor.*	*E. davisii.*	*E. lecontei.*
Shape of shaft of spine.	Almost straight.	Slightly decurved.	Slightly decurved.	Decurved.	Decurved.
Segmented character of shaft of spine.*	Each segmental element passes in an almost longitudinal direction toward the proximal end of the spine for a distance equal to about 2½ times the thickness (dorso-ventral) of the shaft of the spine.	Each element passes obliquely downward in the direction of the proximal end of the spine, for a distance equal to about twice the thickness of the shaft.	Each element passes downward, less obliquely than in *E. giganteus*, for a distance equal to about 2⅓ the thickness of the shaft.	Each element passes downward, almost directly, a distance of about ⅓ the thickness of the shaft. It then extends obliquely downward in the direction of the distal end of the spine.	Each element passes downward and slightly forward for a distance of about ½ the thickness of the shaft. It thence extends obliquely downward in the direction of the distal end of the spine. These characters hold good for only the proximal half of the shaft: the segmented character is entirely obliterated in the more distal part.
Number of primary denticles.	7 (?)	7 (?)	7 (?)	14 (?)	17 (?)
Size of primary denticles.	Smallest: length (height) equals less than ⅓ thickness of shaft.	Small: length equals ½ thickness of shaft.	Medium: length equals about ⅞ thickness of shaft.	Large: length about equals thickness of shaft: hinder denticles slightly the smallest.	arge: length in proximal region about that in *E. davisii*: relatively much larger in distal region.
Shape of primary denticles.	All of about the same shape: differ principally in the size and shape of the small secondary cusp at the anterior margin of primary denticle	All nearly identical.	Resemble each other closely: differ mainly in the rounder tips of the hinder denticles.	Resemble each other closely: slight asymmetry—in side view—of denticles of the mid region.	Graded series: longer and more pointed anteriorly: lower, wider and more rounded posteriorly.
Difference in direction of primary denticles.	All point upward at right angles to axis of spine.	All point upward and hindward, axes of denticles at angles of about 45° to axis of shaft.	All point upward and hindward: anterior denticles at an angle of about 60°, posterior about 40° to axis of shaft.	All point upward at about right angles to the axis of shaft, hind denticles 85°, mid 90°, anterior 105°.	All point upward at about right angles to the axis of shaft; hind denticles 95° to 115°, mid 90°, anterior 80°.
Character of secondary denticles	Large and few (about 8): those of anterior and posterior basal margins of primary denticle forming almost separate basal cusps.	Small, more numerous, but still conspicuous. (Average 15 on either side.)	Smaller and more numerous. (About 24.)	About as in *E. minor*. (About 20.)	Possible traces to be noted on anterior, denticles. If these represent denticles they must have been of very small size (perhaps as many as 30.)

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* The distinctions of the segmental elements would naturally vary to some degree according to the conditions of fossilization: *i. e.*, according to the state of disintegration of the spine prior to fossilization. The age of the individual might also have an important bearing upon this matter.

the most specialized. But there can certainly be but little doubt that *Edestus* is an elasmobranchian fossil. The character of the primary denticles, their shape, denticulated edges together with their bank-like arrangement are almost conclusive evidence, even if unsupported by similar histological conditions in enamel, dentive and nutritive canals.

If, in any event, the five species in the adjoining figure are compared, as, for example, in the above table, a number of very suggestive conditions are readily determined. These might be arranged in somewhat the following order: (I) The primary denticles, small in size in *E. heinrichsii*, tend to become larger, and are relatively largest in the terminal member of the series, *E. lecontei*. They seem also to become more numerous. And (II) in the same order the secondary (marginal) denticles tend to become smaller and more numerous. (III) The shaft of the spine becomes reduced, and at the same time narrows at one end. (IV) In a general way the segmented elements of the shaft tend to shorten their dorsal (*i. e.*, on the side nearest the row of denticles) margin and increase their ventral margin. In this regard, *E. davisii* appears more highly differentiated than *E. lecontei*. A satisfactory comparison of the inclined direction of the primary denticles cannot well be made: it would seem at first that the decurving of the shaft was accompanied with the inclining of the denticles in a single direction, but unfortunately this comparison does not hold good; for where the shaft is greatly decurved, as in Figs. 5 and 6, the inclination of the denticles is in two directions, those in the middle of the spine remain erect, while those at the ends incline in opposite directions from an angle of 90° to the longitudinal axis of the shaft.

In interpreting these conditions generally, one must, I believe, be lead first to the conclusion that the forms in this series are genetically related to each other, more or less nearly, and that one of the two forms *E. heinrichsii* or *E. lecontei* must be regarded as representing the ancestral type, or *vice versa*. That the form represented by *E. heinrichsii* is to be placed at the base of the series, next becomes evident when we consider in evidence the following facts: (1) that it presents in its elements the most perfect serial homology, (2) that its denticles are smaller, *i. e.*, more nearly like those of the neighboring integument, from which they took their ultimate origin, (3) that the secondary denticles resemble closely the primary ones.

The establishment of this series of forms in Edestus seems to the writer of far greater interest than first appears. For by this means an important aid is secured both in interpreting the relations of this puzzling fossil and in throwing light upon a primitive mode of spine formation within the phylum of fishes.

In the first regard to return to the puzzling question * as to what portion of a fish Edestus represented. Accepting as a logical necessity that the fossil is elasmobranchian, the choice of its location cannot be a wide one: it must have belonged either in the mouth region or on the body surface, in the latter case evidently as a spine. As to its belonging in the mouth region the segmented nature of its base has ever precluded the view that it was in any way connected with meckelian or palatoquadrate structures. And as an intermandibular element its position is even less plausible. For in the first place such a view would require *E. lecontei* to be the generalized rather than the most specialized of the different types. And one would have to assume that this intermandibular, which in the only teleostome in which it occurs is in its basis a dermal structure, has not merely been paralleled by the far different jaw conditions of an elasmobranch, but has been paralleled in a cartilaginous tissue. Moreover, even granting the possibility of this, the comparison with an intermandibular element could not yet be made, for in Edestus the shaft is segmented, and in Onychodus its basal portion is unquestionably a single piece.

If Edestus must now be excluded from the structures of the mouth region, it would accordingly fall within the broad class of spines. And this is the alternative which at the present day is very generally accepted. But what manner of spine could it have been? On account of the segmented character of its shaft Henry Woodward has compared it to the pectoral spines of the Teleost *Pelecopterus.* Newberry on the other hand, reviewing its characters in an extended memoir, decides with the clearest and most convincing arguments that the spine was a median one, that it was deeply implanted in the integument and that no fin structures could have existed behind it; it was therefore comparable to the spine series of the sting rays, and its position accordingly might reasonably have been in the hinder trunk region. But even this conclusion does not seem to the present writer altogether a final one. For in *Trygon* the spine series is apparently compound, while in Edestus, the spine, although segmented, is nevertheless a single one. There is, in other words, no common spine shaft in the sting ray from which the denticles take their origin. To make this comparison tenable it must, therefore, be assumed that the individual element of the spine series of *Trygon* represents a segment of Edestus. Of course

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* Cf. especially the views of Hitchcock, L. Agassiz, Henry Woodward and Newberry, Newberry, *op. cit.*

Dr. Newberry never intended to establish definite homologies between these two spines, far less suggest for a moment that there was genetic relationship between them, for the phylogeny of the widely divergent types of rays is too perfectly known to admit of the possibility of their tail spines being a primitive character—any more in fact than the lateral tail spine of *Acanthurus*. His suggestion was merely that the spine of Edestus might be located " in the position of the second dorsal fin on the back or tail of a plagiostome fish (op. cit. p. 9.)."

But the series of forms above described gives us now a somewhat more definite groundwork for a study of the relationships of Edestus. As a flattened spine (*E. heinrichsii*) it bears evidence of having been so imbedded in the integument that a straight row of enlarged shagreen denticles alone protruded above the surface. Each denticle with its underlying basal segment would thus be interpreted, as the present writer has already suggested,* as a metameral element, each denticle with its secondary cusps representing the sum of the shagreen papillæ occurring in a particular region (median dorsal ?) of a metamere, its gouge-like underlying portion the fusion of the bases of these denticles. From these conditions the spine has advanced in its path of specialization, becoming more decurved until finally it assumes a hook-shaped outline. Its hinder end tends at the same time to become differentiated, and in the narrow end of the shaft in *E. lecontei* no trace of segmentation can be determined.

From its distinctly metameral character, as shown in the simpler types, Edestus is certainly to be given a very primitive rank among ichthyodorulites wherever its position may have been. That a large portion of its basal elements was inserted in the integument seems exceedingly probable for all forms, and in this event the curved spines must have been placed either upon the summit of a fleshy, rounded ridge, or within a trench as an erectile spine—the latter doubtless less probably. It is at this point worthy of note that the narrow end of the shaft of *E. lecontei* bears no trace of segmentation. Can this be interpreted as evidence that the hinder end projected above the body surface? In any event does the present evidence gainsay the thesis of Newberry that the spine is bilaterally symmetrical and must, therefore, have found its place in the median line of the body? As far as the writer is aware, all evidence is in favor of this view; no specimen can be pointed to as showing definitely traces of asymmetry. But, on the other hand, it cannot be doubted that this bilateral condition might have attained in spines which were not strictly in the median line. In view of the peculiar terminal of the new species of Edestus, one cannot at present help feeling that its position may have been somewhere on the head region, perhaps above or behind the eye in some early type of Cestraciont. For it is certainly more natural to place Edestus within a group of known spines than to attempt to create for it a station by itself. In the former case the evolution of the remarkable head spines would receive a plausible, if not probable, solution. Beginning with the simplest type of Edestus, situated, doubtless, far back, within the metameral conditions of the anterior muscles of the trunk, the spine has increased in curvature, at the same time tending to occur further and further forward.* A degree of asymmetry may next have appeared, and the peculiar forms of *Listracanthus* and *Erismacanthus* may have culminated the series. At all events this is a suggestion which appears to be offered by the present comparison of the forms of Edestus.

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*Fishes Living and Fossil, pp. 28-30.

The further conclusion afforded by the present comparison bears upon the problem of the origin of spines in primitive gnathostomes. Or, to be more accurate, upon one mode of spine origin, for everyone would be inclined to admit that there may have been several. In the present case the evidence may be accepted as conclusive that a spine-like organ had its origin as a metameral structure whose basal portion lay within the integument, and traversed longitudinally a number (seven at least) of body segments. And that from this condition arose a more or less typical spine shaft, thick at one end and pointed at the other, with indications that its decurved character was accompanied by a firmer insertion of the proximal end, and the eversion of the pointed tip. In this event it is but reasonable to assume that the principal difficulty in accounting for the origin of a spine has been overcome, for we have in Edestus the actual stages in which a horizontal structure belonging peculiarly to the body wall has become so decurved that its proximal end is certainly well nigh vertical. And when once a structure has been evolved which is evidently spine-like, one must admit that the straightening and lengthening of its shaft—processes accompanied by the fusion of the segmental elements and the shortening of the basal line of insertion within the integument—and its perfected dermal encasement and ornamentation become relatively at all events matters of secondary importance. In other words, the present writer is led to believe on the evidence of the spine series in Edestus that the origin of many of the dorsal and head spines of the early gnathostomes, the Ces-

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*This tendency is well known among fishes, *e. g.*, *Pleuracanthus*, *Chimaeroids*, and many teleosts, *Lophius*, *Trachypterus*, *Bregmaceros*, *Patæcus*, flat fishes.

tracionts and Trachyacanthids (Jaekel) in particular, may be traced to segmental structures in which the elements of the shagreen denticle have taken the principal formative part.*

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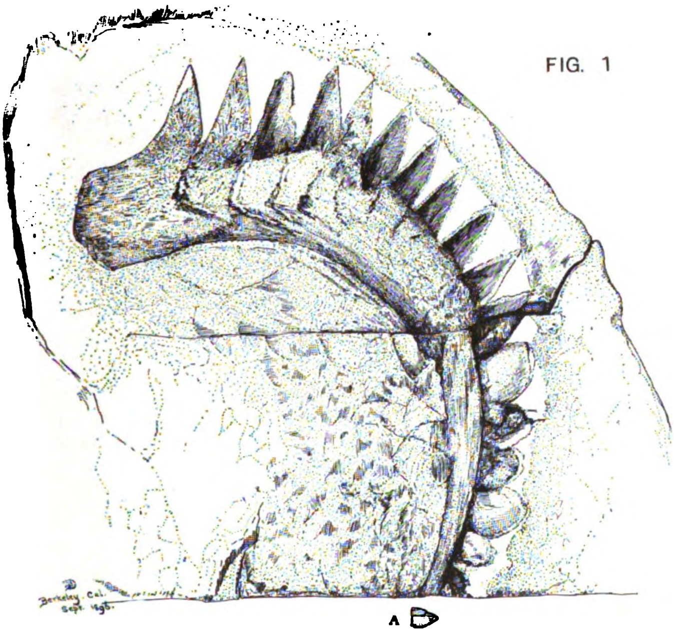
* A second, although kindred, method of spine formation has been referred to in this connection (*Fishes, Living and Fossil*, p. 28). The concrescence of the fin supports in the anterior margin of the fin with a stout sheathing of shagreen denticles, may reasonably have produced the spines of Acanthodians (cf. *Anat. Anz.* vol. xi., pp. 673–679, 1896).

PLATE IV.

Edestus LeContei, n. s. From the Carboniferous of Nevada. See p. 62. Fig 1 A, is small figure below main cut.

FIG. 1

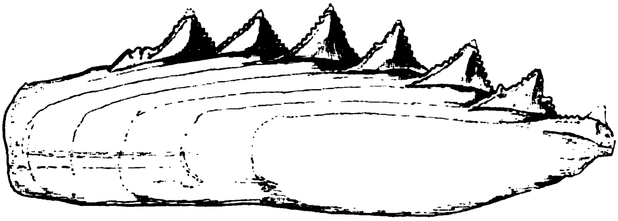


EDESTUS LECONTEI, N. S.

PLATE V.

Comparison of five species of *Edestus*. See p. 63.

FIG. 2



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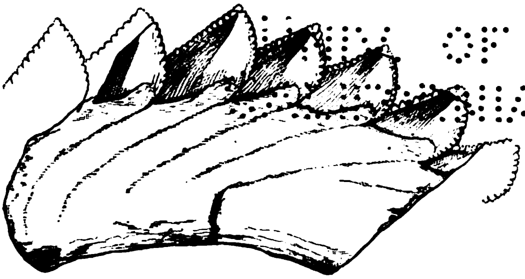
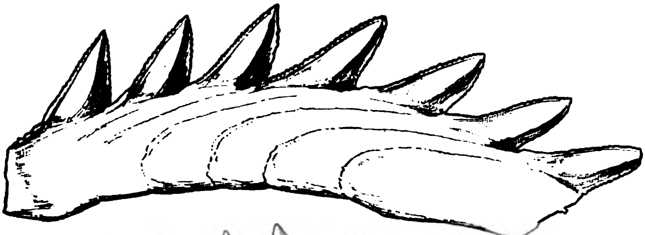


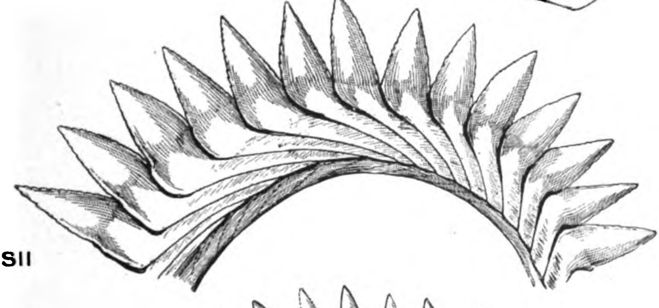
E GIGANTEUS

4



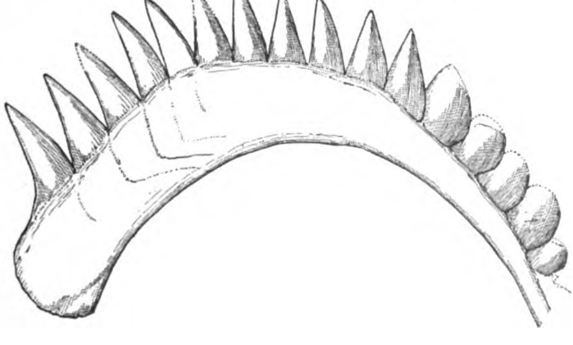
E MINOR

5



E DAVISII

6



E LECONTEI

Notes on the Spawning Habits of the Brook Lamprey (*Petromyzon wilderi*).

Plate XXVII.

By Bashford Dean and Francis B. Sumner.

[Reprinted from Transactions N. Y. Acad. Sci. Vol. XVI., December 9, 1897.]

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NOTES ON THE SPAWNING HABITS OF THE BROOK LAMPREY (*Petromyzon wilderi*).

BY BASHFORD DEAN AND FRANCIS B. SUMNER.

Plate XXVII.

The following notes add a few details to the account of the spawning habits of marsipobranchs given in 1898 by Professor Gage in his admirable work on the lampreys of the Cayuga and Seneca Lake region.* The present observations were made in the uppermost part of New York City upon the brook lamprey, *Petromyzon* (*Lampetra*) *wilderi*, Gage. The specimens were identified by comparison with topotypes kindly loaned by Professor Gage.

The spawning locality was at Lincoln Park, a few rods from the station of the New York and Putnam Railroad at a point where Tibbit's Brook passes under a stone-arch wagon-bridge. Van Cortlandt Lake, into which the brook flows, lies about a mile to the southward. In this direction the lampreys are thus shut off from communication with the brackish water below, by the dam, ten or twelve feet in height, at the mouth of the lake. Nor can they well pass into neighboring waterways, as the brook arises from springs in the vicinity of Bryn Mawr station, east of Glenwood. It is very probable, therefore, that the lampreys, like those described by Gage, spend most of the year in a lake, ascending the brook at spawning time.

The only spawning-ground noted was in the shade of the stone archway where the brook finds its last stretch of gravelly bottom. Above and below this point, the bottom was muddy and the stream on the whole more sluggish. Here on April 16th, three or four dozen lampreys were observed within a few square yards. Many of these were engaged in spawning and nest-building. Three spawning parties were noted, one of which was allowed to remain undisturbed that the process could be closely followed.

The spawning season of our local lamprey is thus found to be nearly a month earlier than that at Cayuga Lake. Professor Gage states that in the latter region, the process lasts approximately from May 8th to May 20th.

The appearance of the lampreys at the time of spawning is shown in the accompanying plate (Plate XXVII) from a pencil sketch made on the spot. Their "nest" was a small gravel-filled pocket, less than a foot in diameter, lying between a number of large rounded stones. The water, 66° F. in temperature, was sweeping across it in a moderately strong current. The temperature of the air at the time was 70° F. The water-depth in the nest was about ten inches.

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*The Lake and Brook Lampreys of New York, especially those of Cayuga and Seneca Lakes. The Wilder Quarter-Century Book. Ithaca, 1898. Pp. 421-493, Pls. I-VII.

The lampreys were in constant movement, sometimes crowding closely together, ten or twelve in number, now and again scattering, many leaving the nest and others returning. Occasionally the nest would be almost deserted. The greatest number was observed about noon-time. The entire party seemed to devote its attention to transporting gravel: the spawning process occurred at irregular intervals and was of very short duration. At first it proved difficult to distinguish males and females. They are almost equal in size and thickness, and the slight differences in fin-characters could not well be seen when the animal was in motion. So too, the erected urinogenital papilla of the male was only occasionally distinguishable. It was later evident, however, that the males were by far the more numerous. Examination of the lampreys taken from this neighborhood, but not from the nest alone, showed that the proportion of males to females was about 5 to 1. It is a reasonable inference, therefore, that this species is polyandrous although this could not be verified in the present instance, the active movements of the animals preventing the observer from following the male till its return to the same female. The mode of mating could, however, be clearly followed. The female, after many circlings about the nest, attaches to a stone and is apparently struggling to move it. Then a male, which up to this point has been diligently stone-moving and is now close by, suddenly seizes his mate "somewhere near the head, he then winds himself half way round the female whereupon the two bend their tails downward and stir up the sand by the most vigorous movements" (Gage).

The actual position of a pair during copulation is shown in the plate. The male attaches the oral disc to the back of the head of a female, somewhat in front of the eye and slightly on the right side. The back of the male is then instantly arched and the tail region wound around the hinder trunk of the female, forming one turn of a left handed spiral. Its increasing curve toward the tail causes the body of the male to here lie at right angles to that of the female. This position was verified in eleven instances. In only one case the body of the male appeared to be wound in the reverse direction. During this process, the body of the male is so rotated that the urino, genital papilla becomes apposed to the cloaca of the female-this result being aided by an upward arching of the latter's body.

The extrusion of eggs and milt which instantly follows is accompanied by rapid vibration of the hinder body region of both male and female, the tails directed brush-like against the sand. The number of vibrations was estimated to be about ten or twelve in the brief time of pairing, about three seconds. Few eggs relatively could, therefore, be extruded at a time. At this moment they may be seen in the water, but they speedily sink with the flurry of sand. The total number of eggs found in one well-distended female was calculated to be 860.

The milt is nearly colorless, causing no cloud in the water at the time of emission. The great length of the slender papilla (4 mm.) suggests that an actual intromission occurs, but of this there appears to be no evidence. The short duration of mating and the immediate outcasting of the eggs are, it is evident, decidedly opposed to this method of fertilization. But to determine by direct observation that no intromission occurs is exceedingly difficult; the pairing takes place unexpectedly and terminates suddenly and during the few intervening seconds the observer is confused by the rapidity of the movement. In a single favorable instance, at the close of the vibration, the papilla was seen to be separate from the cloacal opening of the female. Probably, therefore, the papilla serves to direct the milt upon the discharging eggs rather than as an intromittent organ. In the present nest ovulation took place at irregular intervals, in one case after a lapse of two minutes, but usually after a longer time. In one instance a male attached for a moment to another male, and frequently one would be seen to suddenly seize and pull another away from where it happened to be. Copulation was later observed among lampreys which had been placed in an aquarium. It was here also noticed that the papillæ of the males sometimes remained protruded for many minutes; and in separate individuals, probably of both sexes, the vibratory movement of the tail was frequently observed when no copulation occurred.

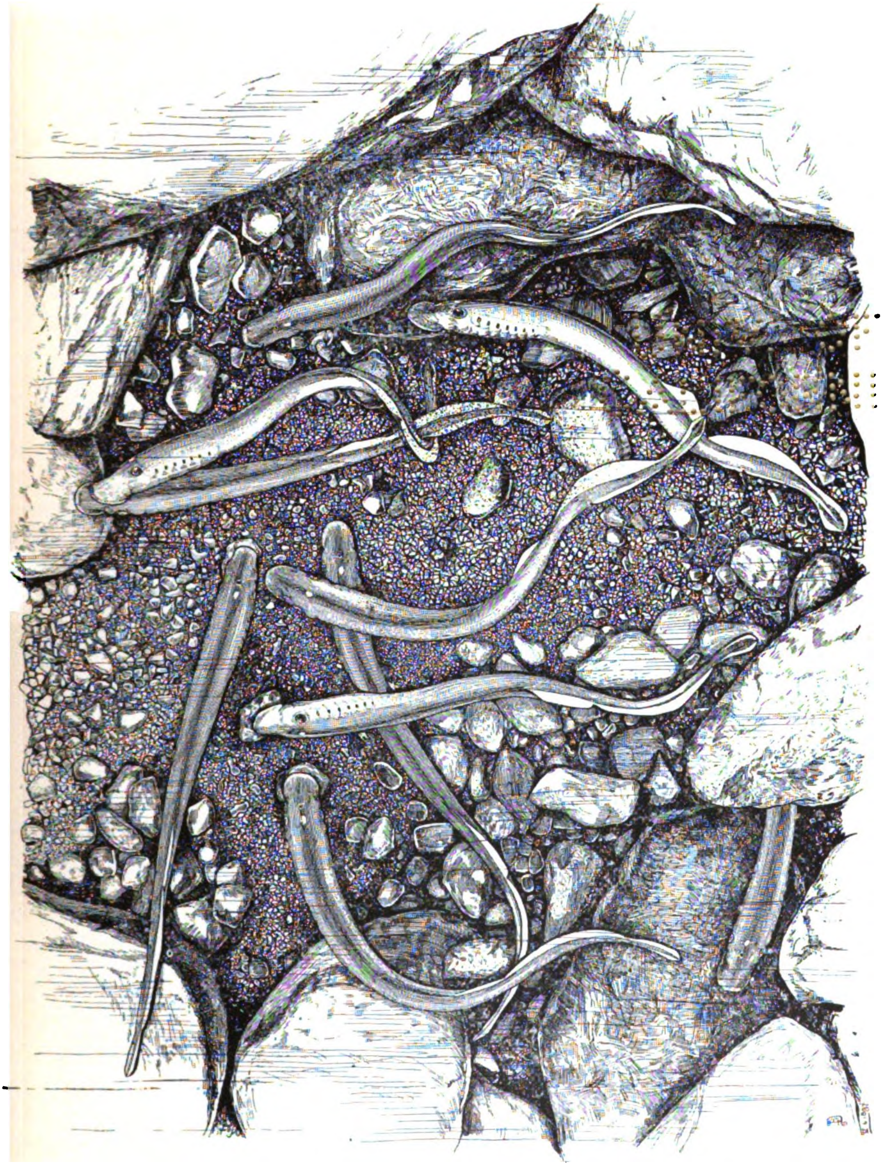
Gage notes that lampreys of this species "are somewhat communistic or gregarious and join in considerable numbers, sometimes eight to ten, to make a common nest." A few details as to the utilization of the common nest were observed in the present instance. The females did not return to exactly the same spot in the nest when ovulating; they seemed in fact to deposit eggs during intermission of stone-carrying, wherever they then happened to be—usually, however, near the margin of the nest. The eggs then often became attached to the sides of the large stones in the neighborhood. No definite mass of rock fragments was accumulated, for although the same lamprey would for a time at least carry stones to a particular part of the nest, the rest of the spawning party would be as diligently carrying them in other directions, often borrowing their neighbors' supplies. Their common result, however, was to stir up the sand and to cause the eggs to be speedily hidden. Stones were collected without apparent regard to the direction of the water current. Gage notes that the lampreys do not join forces to move a large stone. And the present writers, confirming this observation, add that they show a surprising lack of judgment as workers. Their immediate mission is to move stones, and this they do with greater energy than discretion; they occasionally fasten to rocks of great size and do their best to transport them, turning on their sides and struggling violently. An example of this wasted effort is seen at the right of the plate.

Usually, in such a case, the lamprey, finding that its first attempt does not stir the rock, will relax its hold and proceed to the next stone with the same, or perhaps better results. Sometimes, however, as if less easily convinced, it will retain its hold, rest a moment, then recommence the struggle. In one case, a single lamprey, remaining in the nest, tried again and again to move objects which were out of all proportion to its efforts, instinct appearing to lead it to seize any rock surface which afforded him a good attachment, but to avoid at once reattaching in case the stone could not be moved. It seemed, therefore, an evidence of weak memory when in the next circling around the nest the attempt would be made to move the same stones. On another day, similar actions were observed in the case of a solitary male, who for several hours busied himself in a very aimless way, sometimes taking stones from one side of the nest and depositing them on the other, sometimes reversing the process as if forgetful.

The spawning was observed on April 16th. The eggs collected on that day from the sand of the nest were of such a stage that they must have been deposited the same morning. On this day about twenty-five lampreys were captured. On April 18th, nine more specimens were taken but no spawning observed. Some of these latter lampreys were found in another gravelly section of the brook nearly a mile to the northward. Ten days later, no lampreys could be found, nor was a fourth search more successful on May 5th.

PLATE XXVII.

The spawning of the Brook Lamprey, *Petromyzon wilderi*, Gage. From drawing made at Lincoln Park, April 16, 1897, by Bashford Dean. x ½ V. pp. 321-323.



W. D. Matthew

Ueberreicht vom Verfasser.

8

With the Compliments
of Bashford Dean

On the larval development of Amia calva.

By

Bashford Dean,
Columbia College, New York.

With 8 plates and 17 figures in text.

Abdruck
aus den
Zoologischen Jahrbüchern.
Abtheilung für Systematik, Geographie und Biologie der Thiere.
Herausgegeben von Professor Dr. J. W. Spengel in Giessen.
Neunter Band. 1896.
Verlag von Gustav Fischer in Jena.

Nachdruck verboten.
Uebersetzungsrecht vorbehalten.

On the larval development of Amia calva.

By

Bashford Dean,
Columbia College, New York.

With Plates 9—11 and 17 figures in text.

The early developmental history of the Ganoids, *Lepidosteus, Acipenser* and *Amia,* forms an unbroken chain of evidence to connect what are essentially the embryonic characters of the Elasmobranchs with those of the Teleosts. Thus it is known that *Lepidosteus* ¹) is decidedly shark-like in its early developmental features; and that *Amia*, on the other hand ²) is clearly Teleostean; — a range in early ontogeny which can at the least be regarded as providing the most interesting confirmation of the results of palaeontologists ³) as to the phylogeny of the Teleostomes. The Ganoids, in short, have made good their claims to be regarded as an intermediate group: and from this standpoint the further study of their developmental characters might well be expected to demonstrate more definitely the relationships and the interrelationships of the Ganoids and to point out more clearly the lines of evolution of many of the puzzling processes in the specialized developmental type of the Teleost.

The sub-classes of Fishes are broadly separated in the characters

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1) Dean, Early development of Gar-pike and Sturgeon, in: J. Morph., 1895, V. 11, No. 1, p. 1—62, tab. 1—4.

2) Dean, Early development of Amia, 1896, in: Quart. J. Micr. Sc., V. 38, p. 413—444, tab. 30—32.

3) Cf. Esp. Traquair, The Palaeoniscidae, in: Mem. Pal. Soc., 1876, and Smith Woodward, On the palaeontology of Sturgeons, in: P. Geol. Ass., 1889, V. 11, Nos. 1 and 2.

of their development: and indeed even within their sub-groups there occur such striking differences in ontogeny that a morphologist may well wonder to what degree may not adaptations be impressed upon the structures of the embryo. Within a single family like that of the *Cyprinidae* developmental differences may be found which according to older tenets must certainly be interpreted as of far greater significance than those existing between the classes of Reptiles, Birds and Mammals.

It has been noticed that differences in the adaptive characters of the different groups of fishes sometimes appear most strikingly in the stages of latest and earliest development. In the previous papers the writer has explained some of relationships of the most pronounced features of the early development of Ganoids: at present he would undertake to show that the later embryonic and the larval development of the most modern type of Ganoid demonstrates clearly marked transitions to the larval conditions of Teleosts, and that therefore no broad line can be drawn between the typical conditions in the Teleost and those of the most archaic form, *Lepidosteus*, as described by A. Agassiz.

The larval conditions of Ganoids it should be said in introduction are remarkably uniform during the first day after hatching in all forms examined; the larvae of *Lepidosteus*, *Acipenser* and *Amia* at this stage would not readily be distinguished were it not for the well marked difference in their size. In all forms the yolk sac is of the same relative form, and the degree of the differentiation of sense organs, trunk. fins, viscera, surprisingly uniform. But from this time onward the differentiation of the larvae takes place rapidly; on the second day the different forms have become dissimilar; and during the next two days the conditions already suggest those of the mature fish, of *Amia* on the third day, of *Acipenser* on the fourth and of *Lepidosteus* on the fifth to sixth. In tracing these developmental advances we cannot fail to be impressed with the greater precociousness 1) of *Amia* in contrast with the other forms, a distinct nearing accordingly to the Teleostean.

The following arrangement has been made in describing the larval development of *Amia*:

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1) The differences in the rate of development during the first days of development could not have been noteworthy; the larvae of all forms were hatched out and reared in rooms which could have varied but little in point of temperature.

I. Habits of larvae, pag. 642.
II. Description of typical stages from that of the second day before hatching to that of the end of the fifth week, pag. 644.
III. Notes on organogeny, pag. 654.
IV. Conclusions. Comparison of larval characters of this form with those of other Ganoids, and Teleosts (Siluroids especially), pag. 669.

A list of the literature on the embryology of the Ganoids has been given in the Journal of Morphology, V. 11 (1895), p. 54—55. To this is to be added the following titles:

Virchow, H., On the breeding habits and gill vessels of Lepidosteus, in: SB. Akad. Wiss. Berlin, 19. Jan. 1894, p. 33—44.
Furchungsbilder von Amia calva, in: SB. Ges. Nat. Fr. Berlin, 1896, No. 3, p. 41—42.
Nickerson, W. S., The development of the scales of Lepidosteus, in: Bull. Mus. Comp. Zool., Harvard 1893, V. 24, No. 5, p. 114—144.
Jungersen, H. F. E., Die Embryonalniere von Amia calva, in: Zool. Anz. 1894, No. 451.
Dean, Bashford, Spawning habits and early development of Amia, in: Quart. J. Micr. Sc., 1895, V. 13, p. 413—444.

In *Amia*, as in fishes generally, the distinctly larval period may be said to be initiated by the process of hatching and to be continued to the period of the ripening of the sexual products; usually, however, this period is looked upon as referring to the earliest weeks of the free-swimming existence of the fish, — since it is within this short time that nearly every growth process takes place. Thus in the case of *Amia* larvae of the fifth week, although as yet scarcely an inch in length, have attained practically their adult conditions, including the essential fin characters, scales and teeth. And it is to this point that the present outline has been carried: the further changes, those mainly of the genito-urinary system, body and fin proportions, coloration, have been practically omitted from the present discussion.

The later development of *Amia* was hitherto known from the classic memoir of E. P. Allis on the lateral line system, in: J. Morph., 1889, in which many larval stages were figured but not considered apart from the theme of the paper. The only additional account of *Amia*'s later development is the discussion by H. F, E. Jungersen of the larval excretory system, referred to above.

I. The larval habits of the Amia.

After hatching the young fish remains inactive for several days, during both day and night, at all events under the living conditions offered in an aquarium. There is a marked tendency for the larva to attach itself by its sucking disc, but rather curiously it does not appear to become attached to the surrounding stems and leaves of the water weeds; it sinks to the bottom, and there, lying on its side, rests attached to whatever may have been touched. In case no solid object comes in contact, the sucking disc functions nevertheless, becoming covered with sediment. Under natural conditions, as the writer has already noted, the larvae could not be found in the nest during the first days after hatching, and it is perhaps not impossible, as Mr. Kosmak suggested, that they may have been removed by the male fish, attached to him by their sucking disc.

The larvae of the second, third and fourth day exhibit considerable advances; they depend less upon their sucking disc, and occasionally exhibit a spasmodic activity; when touched, they wiggle about rapidly for a short distance, and then sink motionless, resting on their side. As in the younger stage there is a tendency to swim head downward.

The larvae of the fifth, sixth and seventh day have become notably active in their movements, are restless, and can with difficulty be kept even for a few minutes in a single spot. When not swimming they rest on their yolk sac in a normal position, but even then their large pectoral fins are in constant movement, as if serving as balancers. They dislike to be turned on their sides: they breathe with quick movements, the mouth and gill covers opening and shutting widely.

The larvae of the second week begin to attain the characteristic movements of the adult fish; they balance themselves with inconspicuous movements of the fins, pectorals and dorsals. Their firm movements in swimming are now in contrast to the wiggling motions of the younger stages. The caudal fin has become the main organ of propulsion. It is at this period that the young fish have been seen near the surface, attended by the male, in dense swarms often of several thousand. As previously noted by the writer the habits of the young fish under these conditions may be readily observed; the attendant male may be closely approached, and his movements followed; in a slow and cautious way he circles about now over and now under his swarming charges, watchful apparently that the stragglers shall be kept up to the rest; and in their turn the young fishes seem to fully realize that it is their duty to keep as close as possible to the guardian. It was found by the writer by no means easy to approach the male fish without attracting his notice; he appears to be constantly watchful, and when alarmed exhibits the greatest solicitude for his charges; sometimes he backs quietly into some reed-screened pool, hiding below in the shadow of floating weeds, his presence betrayed only by the black mass of larvae about him; at other times he will skulk cautiously away, drawing the swarm after him as rapidly as possible. His duty is clearly to care for his charges, and in the majority of cases when he finds that it is impossible to carry them off with him he will remain quietly and face the enemy. In one instance he was actually pushed away. There can be no question, the writer believes, that the feeling of alarm of the guardian may be transmitted to the young; for in case of need the swarm may be moved more rapidly, the young, excited in their movements, appearing to draw more closely together: under all circumstances they appeared to be careful not to disperse. When the male has been driven away the swarm sometimes becomes so dense that it may be taken almost to a fish by a single dip of a scap-net; if not interfered with it will gradually move away and take refuge among the floating weeds, often so perfectly that no traces of it can be noticed. Exactly to what period the larval *Amia* remains in company with the male fish has not seen determined exactly. The smallest which in any case the writer has observed measured $^5/_8$ inches (slightly younger than that of Pl. 10, Fig. 20), the largest 1 inch (Pl. 11, Fig. 25); and as these notes have been made from a large series of swarms, during a period of about two weeks, there is ground for believing that the time of the guardian's care of the movements of the young extends from — at least — the stage of the exhaustion of their yolk supply to that when the caudal fin and scales have attained the adult outlines; — a time certainly not less than four weeks¹). The rate of growth of larvae of the same

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1) The writer has recently learned from his friend Mr. F. B. Sumner that the period of the attendance of the male is much longer than at first supposed. In Minnesota Mr. Sumner records the taking of a swarm of *Amia* larvae of which the individuals measured 3—4 inches in length, and must have been about four months old; a remarkable fact in connection with them was that all of these young fishes

swarm has been observed to be approximately uniform, the individual differences depending rather upon size than upon actual developmental advances; larvae of apparently the same stage of development have varied in length as much as $^{3}|_{8}$ inches; in some cases, however, the range in development seems, as nearly as could be determined, to have been equivalent to a difference of two or three days.

Upon the dispersal of the swarm the larvae appear to make their way to the well-weeded shallows of the neighborhood; here they remain during the first summer, occasionally taken along adjacent shore reaches in the drawing of the minnow nets. Mr. HENRY G. MEYER, to whom the writer has hitherto referred for his kindness during collecting trips, has stated that during the first summer many of the fishes will be taken in and near the mouths of the small streams which feed the lake chain of Pewaukee. It may at all events be surmised that the habits of the late larvae of *Amia* do not differ widely from those of the prevailing forms of the local Teleosts.

II. Description of larvae of *Amia*.

The latest embryonic stages of *Amia* correspond more closely to those of *Lepidosteus* than of *Acipenser*, the embryo's head and trunk lifting themselves sharply above the neighboring parietal zone and yolk.

Embryo surrounding 200° of the egg's circumference.

At about two days before hatching (138 hours), Pl. 9, Fig. 1, the embryo surrounds about 200° of the egg's circumference. Its trunk, a prominent whitish ridge, is of equal diameter from head to tail; it is sharply marked off from the yolk mass, which at this stage is elongated transversely to the axis of the body. The parietal zone, *p.z.*, is a distinct band, bordering on the one hand the line of the primitive segments and on the other the marginal yolk. The pericardial area, *p*, is now large in size and its distended sides may be seen on either side of the head. The tail is blunt ended, as yet unseparated from the yolk. The head is large; optic lobes are prominent, *o. l.*, overhanging a broad and deep fourth ventricle; sucking disc, nasal pits and auditory sacs are already defined; in the eyes

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(females, therefore, as well as males — although no dissections were made to determine sex) had acquired the characteristic coloration of the male with the prominent orange and black spot on the caudal fin.

the lenses are forming; the two foremost gill slits are established, and the third and fourth already indicated. The pronephric duct, *p.n.*, passes tailward from its origin immediately behind the beginning of the myelon; unlike in *Acipenser*, it is inconspicuous, taking its position close to the trunk, as in Teleosts. Notes on the early structural conditions of the pronephros, brain, hypophysis, chorda, digestive tract and yolk are given below, pag. 654—668.

Embryo surrounding 225°.

A late embryo of 142 hours is figured in Pl. 9, Fig. 2. Its trunk is now a clearly defined ridge upon the egg's surface; it is no longer demarked from the yolk region by the parietal zone as a marginal trench. The pronephric ducts are most prominent at this stage, separate from the trunk region anteriorly, gradually converging tailward and passing within the margin of the trunk. The growth of the tail now separates it from the egg. This condition may well be seen in Pl. 9, Fig. 3, the ventral aspect of this stage. Here too may be seen the outline of the sucking disc, *s.d.*, its large size and distinctly paired character [1]: its uplifted rim consists on either side of about 4—6 papilla-like sucking organs. The heart, too, is also to be outlined in its thin walled and greatly dilated pericardial chamber; it is straight and tubular, showing at either end its diverging component elements. The mouth, *m*, is now a narrow, transversely widened pit, partly concealed by the sucking disc.

Embryo surrounding 240°.

In this stage, 148 hours, Pl. 9, Fig. 4, the trunk has risen vertically from the egg; the hinder trunk region, greatest in vertical width, is now separate from the egg; its terminal is blunt and rounded. Four gill slits are now apparent outwardly; as yet, however, the foremost two have alone broken through, and these but for a small proportion ($^1/_8$) of their length ventrally. The pericardial region is now becoming reduced in size, losing its transparency.

Embryo surrounding 290°.

The region of the hinder trunk in this stage, 160 hours, is seen

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1) There can be no question that the figures of Allis, in: J. Morph., '89, V. 2, p. 463—566, are inaccurate in this regard; the paired character of the sucking disc is shown in surface view and sections from the time of its early appearance till the time of its absorption several weeks after hatching.

in Pl. 9, Fig. 5. The continued elongation of the tail in this stage, taking place within the egg membranes, is accompanied with the torsion of the hinder trunk; this, turning on its side, now grows flatwise, opposing (usually) its left side to the yolk-sac; and in its later growth it assumes a somewhat S-shaped position. Its terminal is still rounded. The entire trunk is whitish, pigmentless, semitransparent; toward its hinder part the somites become more and more difficult to distinguish.

Larva at hatching (Pl. 9, Fig. 6 and, in dorsal view, Fig. 7).

The embryo exhibits movements for nearly a day before hatching; these become especially noteworthy a few hours before the escape from the egg membranes, the tail writhing sometimes slowly, sometimes quickly and spasmodically, from side to side. The movements must undoubtedly be looked upon as the efficient cause of the escape of the embryo from the egg, although during the later stages a decided thinning and drying up of the membranes is to be noted. Upon detaching itself from its membranes the larva lies quietly on its side for some hours, rarely moving. Its head and trunk are whitish, still without pigment; the great rounded yolk sac is pale slate-coloured, in its region below the head a faint tinge of colour indicates the position of the heart. As seen in the figure, Pl. 9, Fig. 6, the body length is somewhat downbent, the tail drooping ventrally to the level of the base of the yolk sac. The conditions of the organs at this stage can readily be made out in the living larva an account of its transparency; the relatively large size of the optic lobes, the breadth and openness of the fourth ventricle are to be noted; the heart is as yet unbent, a short thick tube from whose hinder end diverge the omphalo-mesenteric veins; the mouth pit is just on the point of establishing its opening into the fore-gut, the proctodaeum, a sharp nick on the margin of the fin membrane, has not as yet its connection with the hind gut; the gill region is considerably flattened, dorso-ventrally, against the outswelling yolk; the fifth gill slit is determinable. In the eyes there are as yet but traces of pigment and the lens has not been completely formed. The body segments are to be traced into the hinder trunk but are not as yet differentiated near the bulbous tip of the tail; there is no post-anal gut; the unpaired fins are noticeable, but still inconspicuous; there is as yet little trace of the pectoral fins; the liver is now coming to be formed, distinguishable as a whitened tract on the yolk region at the left side of the trunk; the vitelline vessels become a prominent feature of the dorsal aspect of the yolk sac; the sucking disc is in this stage relatively at its largest size.

Larva of the second day (Pl. 9, Fig. 8).

The straightening of the trunk takes place during the second day, a change accompanied with a great development of the continuous unpaired fin; this now surrounds the entire hinder trunk, and in the caudal region develops a noticeable heterocercy. At the same time the pectoral fin becomes conspicuous, typically fin-fold-like in character, resembling the corresponding stage in the fin growth of the older Ganoids; it contains about seven (metameral) mesoblast buds. An elongation of the yolk sac accompanies these changes; and the entire head region has become distinct from the sac and greatly enlarged. At the side of the head the dermal operculum is enclosing the gill slits; the auditory vesicle is clearly defined; and the formation of the lens has taken place. There is a general loss of the transparency of the head and anterior trunk region; pigment patches become evident; the brain vesicles can no longer be distinguished through the head wall. The blood has now acquired a reddish colour and the pulsation of the heart can be followed; the long caudal vessel forms a broad band at the ventral margin of the somites of the trunk. Mouth and anus are established; the pronephric ducts are to be traced above the line of the hind gut, and may be seen to unite just above the anus; their common opening to the exterior appears to be on the point of formation. The head surface shows a faint outmapping of the sensory canals; the nervus lateralis vagi is seen to have pushed its way hindward along the side of the trunk to near the pectoral region (cf. Allis, op. cit.).

Larva of the third day (Pl. 9, Fig. 9).

The advances in this stage include: pigmentation, increased size and the distinctness from the yolk sac of head and trunk; enlargement of the pectoral fins and of the dermal operculum, which has now entirely overlapped the region of the gills; the U-shaped condition of the heart; the separation of the chin region from the yolk; the distinct appearance of the thickened tracts of sensory epiblast in the head surface; the progress of the nervus lateralis vagi to that portion of the mid-lateral line of the trunk immediately above the hind margin of the yolk sac.

Larva of the fourth day (Pl. 9, Fig. 10; dorsal aspect Pl. 9, Fig. 11; ventral aspect Pl. 9, Fig. 12).

In this larva there is an evident reduction in the size of the yolk sac, the latter's hinder end has now become pointed, its ventral side concave; anteriorly it is overlapped by the growth of the gular isthmus of the opercular flaps; these are now seen to open and shut, showing that the active process of breathing has begun; gill filaments are established, but as yet are small in size. The chin region is now prominent; conical teeth appear; the iris coming to be formed, shows on the ventral side a well marked break due to the connection of its growth with the choroidal fissure; the heart has completed its S-shaped course. The thickening of the ectodermal tracts of the head surface is now to be prominently noted; and the pushing of the nerve tract of the lateral line has progressed along the trunk region into the anterior part of the tail. The outline of the larval caudal fin is at this stage relatively largest; the pectorals, much enlarged in size, indicate that the fin axis has come to protrude from the body wall, and that it is already surrounded by the rapidly growing dermal margin of the fin. At this and earlier stages the pectorals are situated on the yolk sac close by the side of the trunk, their planes diverging somewhat tailward. In the ventral view of this larva, Pl. 9, Fig. 12, a remarkable arrangement of pigment may be seen in the chin and sucking disc, demarking in this region apparently the lines of the sensory tracts; especially striking is a cross line of pigment traversing both halves of the sucking disc.

Larva of the fifth day (Pl. 9, Fig. 13; dorsal view Pl. 9, Fig. 14).

A notable decrease in the size of the yolk sac characterizes this stage also; the sac's hinder end is now reduced to a pointed outgrowth, now no further from the body than the rim of the anal finfold. The size of the larva has on the other hand notably increased; its head is especially prominent; the mandible is now distinct, occasionally opening and closing; the nasal sac is prominent, its opening somewhat pear-shaped, — at its narrow end near the eye will be constricted off the posterior naris; the iris is now metallic in lustre, marked here and there with dark pigment. The mucous canal tracts are to be clearly followed on the head surface; the lateral line has passed into the region of the tail tip and has turned ventrally, as Allis has shown, into the position of the median line of the definitive caudal fin. The continued growth of the opercular folds has by this time enclosed the region of the heart, although their translucency still permits the heart's outline to be seen. The principal change in the fins is the increased growth of the pectorals; these have now a stout muscular base and exhibit their first movements. The caudal vessels, *c. v.*, are now less prominent on account of the enlargement and thickening of the muscle-plates in the ventral region of the trunk; a sub-intestinal vein, *s. i.*, is noted. The anal opening is now obscured by the longitudinal creasing at this point of the dermal fin; it is now, judging from surface view, that the pronephric ducts, *p. n.*, establish their outer opening.

Larva of the sixth day (Pl. 10, Fig. 15; dorsal aspect in Pl. 10, Fig. 16; outline of distal end of sucking disc in Pl. 10, Fig. 15 a).

A general modelling of the head and yolk sac accompanies the size growth of this stage. In the head the brain is becoming surrounded by the cartilaginous cranium; this growth, however, is not as yet so complete as to obscure the profile of the fore-, mid- and hind-brain, as noted in the figures of the larvae of fifth, fourth, third and second days. The head contours are being filled in by the growth of the musculature of the opercula, gill arches and jaws. In the latter notable advances are present; the membrane bones, premaxillary and maxillary are forming, and give at once an *Amia*-like appearance to the young fish; their establishment has proceeded pari passu with the reduction in size of the sucking disc. Its distal outline at this stage is shown in Pl. 10, Fig. 15 a. The lower jaw has also the beginning of its adult characters; its increased size becomes more conspicuous by its constant movements in breathing; the beginnings of the jugular plate, *jug.*, appear in the angle between its rami. A general outlining of the thickened epithelial tracts of the mucous canals can now be followed, especially in the temporal and supra-orbital regions, where the closing over process so admirably described by Allis is now taking place; this process has already occurred along the sides of the trunk and renders the lateral line less conspicuous in surface view. The great reduction in the size of the yolk sac gives the larva a tadpole-like appearance: around the sac's forward end the enlarged opercula have become neatly modelled. There is a noteworthy enlargement of the pectoral fin both in basal and dermal parts; it has at present somewhat the appearance of a shark's fin, a monoserial archipterygium, the dermal margin having made little advance is surrounding the hindward projecting fin axis.

Larva of the seventh day (Pl. 10, Fig. 17; dorsal aspect Pl. 10, Fig. 18).

The chondro-cranium is nearly completed at this stage, giving the frontal region somewhat its adult appearance. The sucking disc is reduced to a mere tubercle and is no longer functional; maxillae and premaxillae are established; the opercula have increased widely in outline, broadly enclosing the front of the yolk-sac region. The mucous canal tracts of the head are now mapped out most favorably; they have sunken into the skin as whitish lines and are gradually becoming darkened at various points by the overlapping tissue of the margining ledges. The pectoral fins have greatly increased in size and are in constant motion; they now suggest the archipterygial stage of the adult *Polypterus*, — especially interesting is this in its adverseness to GEGENBAUR[1]) in his last paper on the Archipterygial theory of the paired limbs, since it has been seen to have been preceded by the shark-like fin-form, and this in turn by the ptychopterygial type in its early dermal fold. At this stage the nasal opening, greatly constricted, is becoming divided into its anterior and posterior divisions by a dermal outgrowth of its anterior margin, an ontogenetic stage suggesting the adult conditions of sharks. The enlargement and strengthening of the muscle plates of the trunk should also be noted. The eyes, it is interesting to remark, are for the first time in constant movement, turning about on all sides in the most marked way, — the development of the eye muscles seeming to be accompanied by the need of their constant exercise, for at no later period are their movements so prominent.

Larva of the tenth day (Pl. 10, Fig. 19; jugular region in Pl. 10, Fig. 19a, sucking disc b).

From this stage onward the larva has to acquire but the minor characters of the adult. The general body outline has become established, the yolk sac largely absorbed, its walls now entirely surrounded by downgrowing muscle plates. The head region is distinctly that of the adult, its skeletal and muscular elements clearly modelled; mucous canal openings have now been formed by the process of enclosing the sensory tracts begun in the preceding stage; the mouth has its mature form and movements; the nasal openings are established;

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1) Morph. Jahrb., V. 21, Heft 1, p. 119—160.

the beginnings of the opercular series of dermal bones have appeared. The sucking disc is greatly reduced, although it does not in fact disappear entirely (histologically) for several weeks; it remains as a small flattened pad, scarcely to be noticed in the profile of the head, although its distal surface, Pl. 10, Fig. 19b, still shows slight depressions. Its atrophy takes place first proximally, later marginally; the cells of its deepest tissue become greatly vacuolated and form a sponge-like mass, and the cell wall which here forms its outer boundary, gradually encroaches; the cells of the centro-distal region are the last to retain their early character. The anus appears in the now widely separated gap between the fin-folds of the abdominal and anal regions. Muscle plates are to be traced ventralward on the abdominal walls. The advances in the development of the fins include: the growth of the pectorals, the bases of which, changing from their crossopterygian character, are becoming less distinctly lobate as the dermal rays make their appearance; the origin of the ventral fins as minute dermal folds, arising independently, however, of the unpaired abdominal or anal; the appearance in the unpaired fins of supporting elements; these, the homologues of the radial cartilaginous fin supports of Wiedersheim, take their origin along the dorsal body wall in a continuous series, most prominent in the hindmost region and on the ventral side in those portions of the unpaired fin which will later become constricted off as anal and caudal fins; of these the outlines will be seen to be now suggested. These supporting elements make their appearance as in the Teleosts some time before dermal rays are to be determined, the latter when they come to arise seeming to bud out from their distal ends, spreading out like tapering fan rays toward the free margin of the fin. So closely are these elements then fused that it becomes impossible to determine their juncture; the histogenesis of the dermal rays appears to offer the same characters as demonstrated in Teleosts by Harrison[1]). Another interesting feature in the larval development of *Amia* is the mode of appearance of the jugular plate. This, although an unpaired structure, might reasonably on purely a priori grounds be expected to have had a paired origin, — that is if we accept the view that the jugular plates in the various sub-groups of the early Teleostomes have not been involved independently. It is accordingly of great interest that in this stage the jugular plate, Pl. 10, Fig. 19a *jug.*,

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1) in: Arch. Anat., V. 32, p. 248—278.

is making its appearance as distinctly a paired structure. The ceratohyals, *ch.*, can be clearly made out passing from the jaw hinge to the hypobranchial region; a slight depression immediately behind the mandibular symphysis indicates the uplifting of the glossohyal; immediately behind, its posterior border slightly uplifted, the jugular may be seen to consist of two pairs of elements. These, however, are already closely apposed, forming together the shield-shaped mass, whose growth and dermal calcification will shortly give it the appearance of an unpaired structure. It follows, therefore, that there is no need of regarding the jugular plate of *Amia* as having had an independent origin from the paired structures of the early Teleostomes, — although one must acknowledge that it is decidedly remarkable that so ancient a feature of dermal armoring should have been retained in this most modern of Ganoids, while lost in the gar-pikes and sturgeons; its function must obviously have been an important one to have caused it not merely to be retained but to become enlarged and specialized. Its relation to the sensory canals of the lateral line system, as shown by ALLIS, is noteworthy in this connection.

Larva of about the fifteenth day (Pl. 10, Fig. 20; ventral aspect Pl. 10, Fig. 21).

A great advance in the conditions of the fins is apparent in this stage, and a corresponding growth in the breadth and thickness of the hinder trunk. The length of the dorsal fin is clearly indicated; the line of the dorsal fin-rays, *r.*, with their corresponding row of basal supporting elements, *b.*, terminate abruptly at a position which will mark the hindmost point of the dorsal fin of the adult. There is no trace of a series of larval fin supports surrounding the protocercal tail tip to connect the dorsal fin with the definitive caudal, as would naturally be supposed, if this, according to SHUFELDT, were the ancestral condition in *Amia* (cf. U. S. Fish Commission Rep., 1883, Explanation of fig. 25). In the various fins the number of radialia which may now be counted are as follows: dorsal 57, caudal 20, anal 10, anterior anal — a larval element as yet persistent — 0, ventral 0 (?), pectoral 15. Comparison of these numbers and those of additional larval stages 1) with the adult's leads to the conclusion

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1) In the opposite table a general view may be had of the numerical increase (approximate only — i. e., as counted in surface view in single specimens) in radial fin supports at successive stages.

that the perfection in the fin supports takes place in the following order in time, 1) dorsal, 2) anal, 3) caudal, 4) pectoral, 5) ventral. In the pectoral fin the increase in the number of the radials takes place in the region of the ventral (i. e. posterior) fin margin, near the enlarged base of the fin. The ventrals, *v.*, are now elongated, lappet-like. In the head region the mucous canals exhibit but few advances; the tube-like outgrowth of the anterior naris, *a. n.*, is noteworthy; the enlarged size of the opercular flaps causes their broad overlap ventrally; in the gular region, however, they are overspread by the growth of the jugular plate, *jug.* This maintains at its distal end dermal connection with the ridges of the ceratohyals. To this ridge are now appended the branchiostegal rays, a dozen in number as in the adult. These begin ventrally near the jugular region small, tapering, slender, and increase in size as their series passes lateral toward the opercula, with which, indeed, they appear in close serial homology. The exhaustion of the yolk material takes place during the final part of the larva's second week, and results outwardly in the closer modelling of the wall of the abdomen and that of the trunk.

Radialia in larva of days	7	15	22	35	Adult
Dorsal	47	57	57	? 70	58
Anal	9	10	10	13	13
Caudal	16	20	20	21	24
Pectoral	14	17	19	22	22
Ventral	0	? 0	? 3	6	9

Larva of about the twenty-second day (Pl. 11, Fig. 22; dorsal aspect Pl. 11, Fig. 23; ventral Pl. 11, Fig. 24).

The following advances characterize this stage: the marked outgrowth of the caudal fin, *c.*; the outlining of the definitive anal, and the reduction of the larval caudal-anal and pre-anal fin-fold, *c-a.* and *ant. an.*; the closer welding of the line of muscles of the basal fin supports with the muscles of the trunk; the distal broadening of the ventral fins; the first appearance of scales in the anterior region of the lateral line; the outlining of the pre-, sub- and interopercula. A broad transparent linea alba, *l. a.*, permits a glimpse of the ventral viscera, notably the ventricle and the conus and bulbus arteriosus.

Larva of about the thirty-fifth day (Pl. 11, Fig. 25; ventral aspect Pl. 11, Fig. 26).

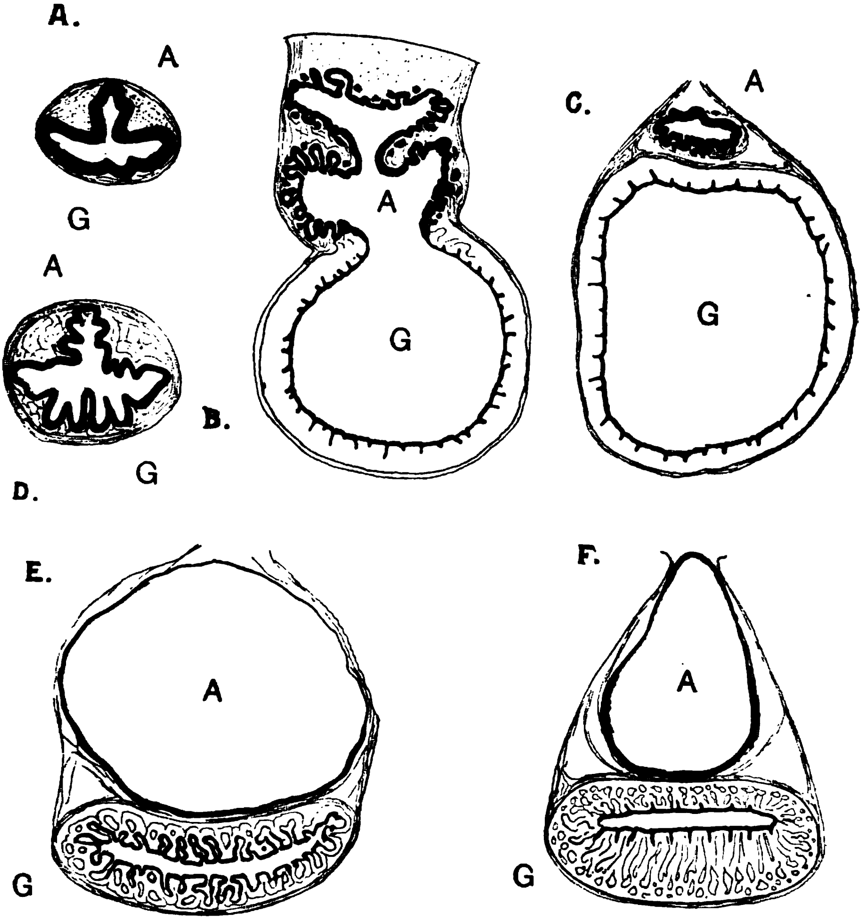
This stage, the latest to be figured in the present paper, has acquired the main outward features of the adult. The fins suggest clearly their mature forms; the intervening membranes of the larval unpaired fins have become greatly reduced, *c-a.*, that of the pre-anal abdominal region having entirely disappeared; the definitive caudal, *c.*, has now supplanted the larval caudal, and leaves it reduced to the condition of urostyle, *u.*, entirely separated anteriorly from the posterior margin of the dorsal. The outline of the mature ventral fin is now attained, and its basal portion suggested. In all fins dermal rays, *d. r.*, have made their appearance at the distal ends of the radials; to these their ontogenetic relations have not been determined, nor yet their subsequent outgrowth, and formation of splits and joints. In the entire trunk region the appearance of scales may now be noted although they have their greatest prominence in the region of the lateral line: unlike in *Lepidosteus* they do not exhibit cusp like outgrowths: they at once attain their oblong shape and their growth suggests closely that of the Teleost. The head growth is marked by the general outmapping of the dermal bones of the cranial roof, and by the definiteness of those of the opercular and orbital regions. To these, however, the relations of the mucous canals are as yet simple; for the subsequent growth of the mucous canals cf. ALLIS. The jugular plate, *jug.*, has now its characteristic position and proportions.

III. Notes on organogeny.

The general form-changes in the larval *Amia* have been briefly reviewed in the foregoing pages. Notes on several of the more important features of larval organogeny may now be added, derived from a study of serial sections: i. e., a) Mouth, teeth, gullet, swim bladder; b) anus, postanal gut, neurenteric canal, hinder excretory ducts; c) liver, yolk; d) pronephros; e) brain, neuromeres, hypophysis; f) sense organs, sucking organ, ciliation.

a) Mouth, teeth, gullet, swim-bladder.

The formation of the mouth in *Amia* differs little from that in *Lepidosteus*, Sturgeon and in Teleosts generally. The stomodaeum establishes its opening into the fore-gut earlier than in other Ganoids, about the same time in fact as in the sea-bass (H. V. Wilson); it is wide and slit-like at first, and becomes gradually pit-like and rounded.



Figs. A—F. Transverse sections of gut of larval *Amia* showing early conditions of the swim-bladder. Figs. A, B, C, Larva of about the tenth day sectioned through the opercula and through the anterior and posterior margins of the pectoral fins. Figs. D, E, F, Larva of about the twenty-second day, sectioned through corresponding planes.
A Air bladder, *G* gut.

At no time does it add evidence to the view that the mouth is of gill-slit origin 1); nor does it show any traces of median asymmetry.

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1) Cf. Willey, Amphioxus and the Ancestry of the Vertebrates, p. 281, summarizing the results of Dohrn, Clapp and H. B. Pollard.

Teeth take their origin at the bottom of deep tube-like insinkings of the mucosum: these are implanted irregularly in the dentigerous regions, without any apparent attempt at the production of a general dental trench. The pharynx of the early stages, Pl. 9, Figs. 1—8, is a well marked cavity although its dorsal and ventral walls are closely apposed; in the gullet the lumen is wanting, a secondary condition known to be of very general occurrence among fishes since the time of the studies of Balfour. The reopening of the gullet takes place at about the stage of Pl. 9, Fig. 10. And at nearly the same time the swim-bladder takes its origin as a crease-like invagination of its dorsal wall; its rapid growth has by the stage of Pl. 10, Fig. 19, given it the following characters: anteriorly, in the transverse plane of the opercules a narrow dorsal longitudinal slit, Fig. A; in the plane of the bases of the pectorals the swim-bladder's dorsal wall becomes enlarged, bilobed, although still retaining its opening to the gullet, Fig. B; in a plane immediately hindward of the tips of the pectorals it has become distinctly tubular. At the stage of Pl. 11, Fig. 22, the swim-bladder has assumed the following characters: in the transverse plane corresponding with that of Fig. A, its opening into the gullet is slit-like, its neighbouring mucous walls notably convoluted, Fig. D; shortly behind this position, in a plane still passing through the opercula, Fig. E, the swim-bladder is a large thin and smooth walled chamber, attached to the dorsal wall of the anterior portion of the stomach by connective tissue but otherwise unconnected with it; this attached condition the swim-bladder maintains as it passes down the mid-dorsal region of the visceral cavity, its diameter first increasing then diminishing till it terminates slightly in advance of the plane of the ventral fins. In its hinder region, Fig. F, it is somewhat deeper than wide, with thicker vascular walls. In this stage the adult conditions have practically been attained.

b) Anus, post-anal gut, neurenteric canal, hinder region of excretory ducts.

In Teleosts generally the anus is formed at a remarkably early period, — in *Serranus* (H. V. Wilson) before hatching. In the Ganoids its formation is later, at about the same time as the mouth opening, — in *Amia* at about the beginning of the second day. In Teleosts the abbreviation of the process is probably the cause of the formation of the anus directly, i. e., without proctodaeum; in *Amia*, on the other hand, a proctodaeum, although small, unquestionably occurs, as a nick in the margin of the ventral unpaired fin, Pl. 9, Fig. 6 *p*. A similar condition occurs in *Acipenser* and *Lepidosteus*.

A post-anal gut is suggested in the sagittal section of the tail of a late embryo (slightly earlier than that figured in the present paper in Pl. 9, Fig. 1) shown in Fig. G *PAG*. But throughout the early stages in the growth of the tail region there is no trace of a neurenteric canal. It will be remembered that in *Amia* the neural axis, as in Teleosts, is formed as a solid keel-like insinking of the ectoderm; and that its lumen is acquired at a later period — later than the blastopore's closure. A study of serial sections demonstrates that this lumen extends hindward into the outgrowing tail bud, as in Fig. G separate *I* and terminates blindly in the undifferentiated tissue of the caudal mass, *U*. No traces of a connection have been found between the cavity of the medullary tube and the virtual lumen of the post-anal gut, *PAG*. A similar condition has been described in *Lepidosteus*, although there can be no doubt that a truly shark-like neurenteric canal occurs in *Acipenser*.

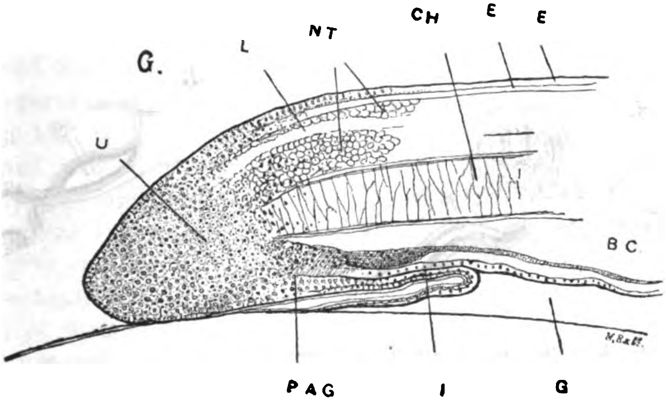


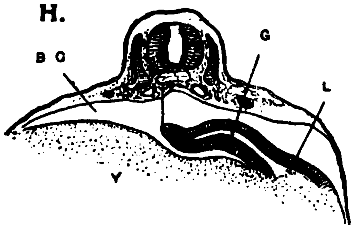
Fig. G. Sagittal section of the tail region of embryo surrounding about 195° of egg's circumference. *BC* body cavity, *CH* notochord, *E*, *E* inner and outer layer of epidermis, *I* intestine, *L* lumen of neural tube, *NT* neural tube, *PAG* region of post-anal gut, *U* undifferentiated tissue of tail.

The relation of the pronephric ducts to the hind gut and the position of their common opening in the region immediately behind the anus have already been noted. In their tailward growth the ducts, keeping close to the intestine, have been found to remain separate till they have attained a position slightly above and in front of the anal region (Pl. 9, Fig. 6); in this position they fuse, and, continuing their growth, they bend downward, tailward of the rectum, and establish their outer opening. Very similar conditions have been described and figured in the Teleosts.

c) Liver, yolk.

The liver takes its origin in the stage of Pl. 9, Fig. 4, as a broad upwardly directed fold of the dorsal wall of the gut. In the stage of Pl. 9, Figs. 6, 7 *l*, it appears in surface view as a whitish mass lying on the dorsal wall of the yolk sac immediately at the left side of the trunk. It is now pocket-like, its blind end directed somewhat outward and forward, its hinder portion somewhat flattened, and communicating with the cavity of the gut through a narrow slit-shaped opening. These conditions are in part illustrated in Figs. H, J, K, transverse sections through the region of the yolk sac of an embryo shortly before hatching; thus in Fig. H, the hindmost section, the position of the liver is shown at *L*: anteriorly the liver becomes a well marked diverticulum of the wall of the gut; in Fig. J the lumen of the liver, *L*, is separate from that of the gut, *G*, although it still is continuous ventrally with the yolk, *Y*; in the foremost section, Fig. K, passing through the anterior tip of the liver, the gut has become flattened dorso-ventrally, is broadly fused with the dorsal wall of the body cavity, and is separate, below from the yolk, and at the side from the liver. The subsequent growth of the liver is as follows: its cœcal condition becomes ramose, and the organ enlarges greatly in size, fitting itself into the space at the side of the visceral cavity, and between the stomach and intestine. In a transverse

H.



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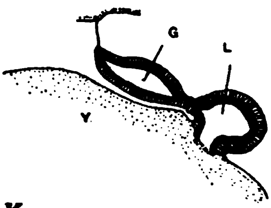

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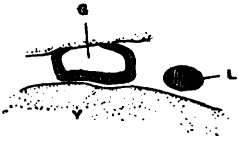
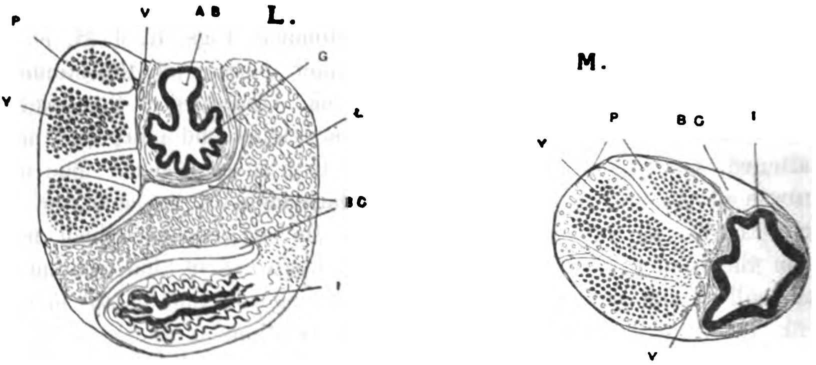


Figs. H—K. Transverse sections of *Amia* shortly before hatching. Fig. H through gut and hindmost portion of liver. Fig. J through gut and middle region of liver. Fig. K through gut and anterior tip of liver. *BC* Body cavity, *G* gut, *L* liver, *Y* yolk.

section of a larva of about the fourteenth day, Fig. L, the liver may be seen to occupy this position: inferiorly it is confluent with the intestine, *i*, in the region of the definitive gall duct; dorsally its finely ramose substance appears to be attached to the peritoneum, and between the gullet and the intestine it extends to the opposite visceral wall: it here becomes apposed to the ventral wall of the yolk sac, although not fusing with it.

The relation of the yolk sac to the alimentary canal may next be noted. The origin of the dorsal wall of the gut has been outlined in the writer's paper "On the early development of Amia." The lumen of the mid-gut appears to be formed by the gradual uplifting of the head region of the embryo, and the gut comes to be constricted off from before backward: thus at the stage of hatching the hinder gullet and the anterior region of the stomach, Figs. K, J, H, is entirely separated from the yolk; the hinder portion of the stomach, however, Fig. H, is confluent with the yolk. Hindward of this position the dorsal wall of the gut becomes constricted and more and more flattened, the lumen becoming reduced to a mere fissure. The outgrowth of the tail region causes an enlargement of the cavity of the gut, Fig. G, as well as giving rise to the evagination which is to form the hinder intestine, *I* and *PAG*; hindward of this evagination the wall of the gut flattens to the underlying yolk and shortly merges with it. It will thus be seen that the relations of the yolk to the alimentary canal differ but little from those of the typical meroblastic Vertebrates, the Teleosts in particular. From the latter, however, *Amia* differs broadly in the mode of its yolk absorption. In *Serranus* (H. V. Wilson) the liver becomes attached to the yolk-mass and aids directly in its absorption — a process, "probably akin to intercellular digestion", in which the liver "cells establishing a connection with the yolk, form a feeding or absorbing surface, which, as it incorporates new material on its yolk side, as constantly splits off new cells on its liver side". In *Amia*, on the contrary, the liver has no direct connection with the yolk, its growth being supplied largely by the vitelline (and intestinal) veins. That this condition may well prove ancestral in the evolution of bony fishes (*Serranus*) appears not unnatural when the following relations of the later yolk absorption in *Amia* are considered. In the larval *Amia* of seven days the transverse section of the liver region, Fig. L, already noted has shown that the yolk material has become largely absorbed: within three or four days, indeed, it will have entirely disappeared. In this section the yolk mass is seen to be closely apposed to the hindmost part of the gullet, enclosed in fact within its peritoneal investment; it has become broken into lobes, from whose translucent, periblastic margins the vitelline capillaries, nutriment laden, are passing liverward, uniting and enlarging till they become the vitello-intestinal veins, *V*. Hindward of this region the yolk mass has increased somewhat in size, but retained its intimate relation with the gut; in Fig. M, a transverse section through the hind gut, these conditions are illustrated; the yolk mass, *Y*, lies as before morphologically within the side wall of the gut, enclosed by its peritoneal sheathing; its substance is broken into lobes, along whose margins on the side of the gut the blood vessels are converging liverward, — these blood vessels in turn arise in the vitelline capillaries which furrow the yolk segments and draw their nutriment from the yolk's peripheral zones (mainly from the sides away from the gut). It will thus be seen that the yolk-nutriment supply of *Amia* reaches the liver through vitelline veins which pass between the yolk mass and the gut; accordingly it follows that the conditions in *Serranus* would be attained without wide caenogenetic changes; for the growth of the liver occurring in Teleosts more precociously, could naturally cause the shortening of the length of the vessels connecting it with the yolk; by this process the liver would early become attached to the yolk and receive its vascular supply from the capillaries directly: these, shortened in turn by still more precocious development, would, it is evident, ultimately be replaced by the growing tissue of the liver —



Figs. L, M. Transverse sections of visceral region of larva of seven days. Fig. L through the gullet. Fig. M through the intestine. *AB* Air bladder, *BC* body cavity, *G* gullet, *I* intestine, *L* Liver, *P* periblast zone of the yolk, *Y* yolk.

as in *Serranus*. And it is further evident that the more intimate the relation of the yolk to the liver became, the less intimate would be its connection with the gut, — i. e., the earlier it would become separated from the wall of the digestive tube, — as the conditions in *Serranus* demonstrate.

A final word contrasting the mode of development of the liver in *Amia* and in Teleosts. In this regard the precociousness of *Serranus* is again to be noted. The liver here arises, not as a caecum, but as a solid outgrowth, which branches almost at once and later acquires a lumen through the dissociation of its cells.

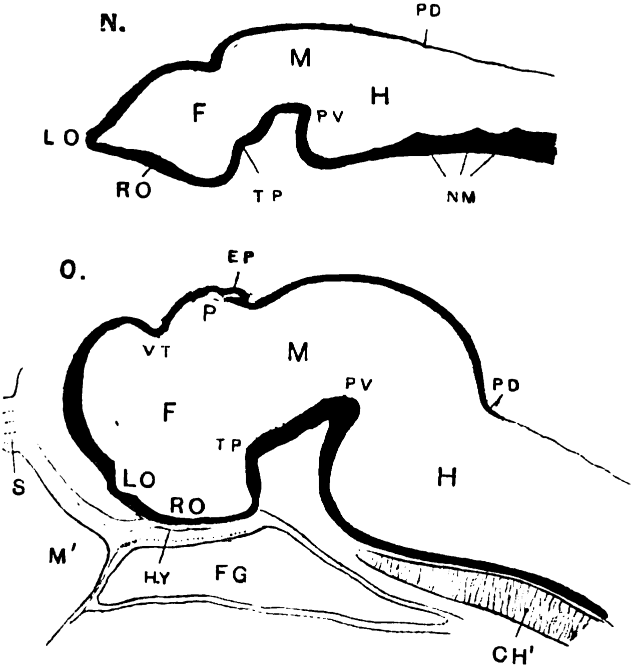
That the periblast nuclei are directly concerned in the formation of blood cells the present writer has been unable to decide. In the Teleosts this disputed view certainly receives no confirmation, but in *Amia*, where the yolk material has still its primitive relations to the intestinal veins, the conditions appear to be worthy of more careful study. Although the writer has not attempted to follow the histogenesis of the blood cells, he has noted that cells occur in the peripheral periblast, that these especially on the side away from the gut, become greatly enlarged and then undergo division, and that their products, lying in the outermost periphery of the periblast zone, certainly resemble very closely the blood cells which fill the capillaries immediately adjoining.

d) Pronephros.

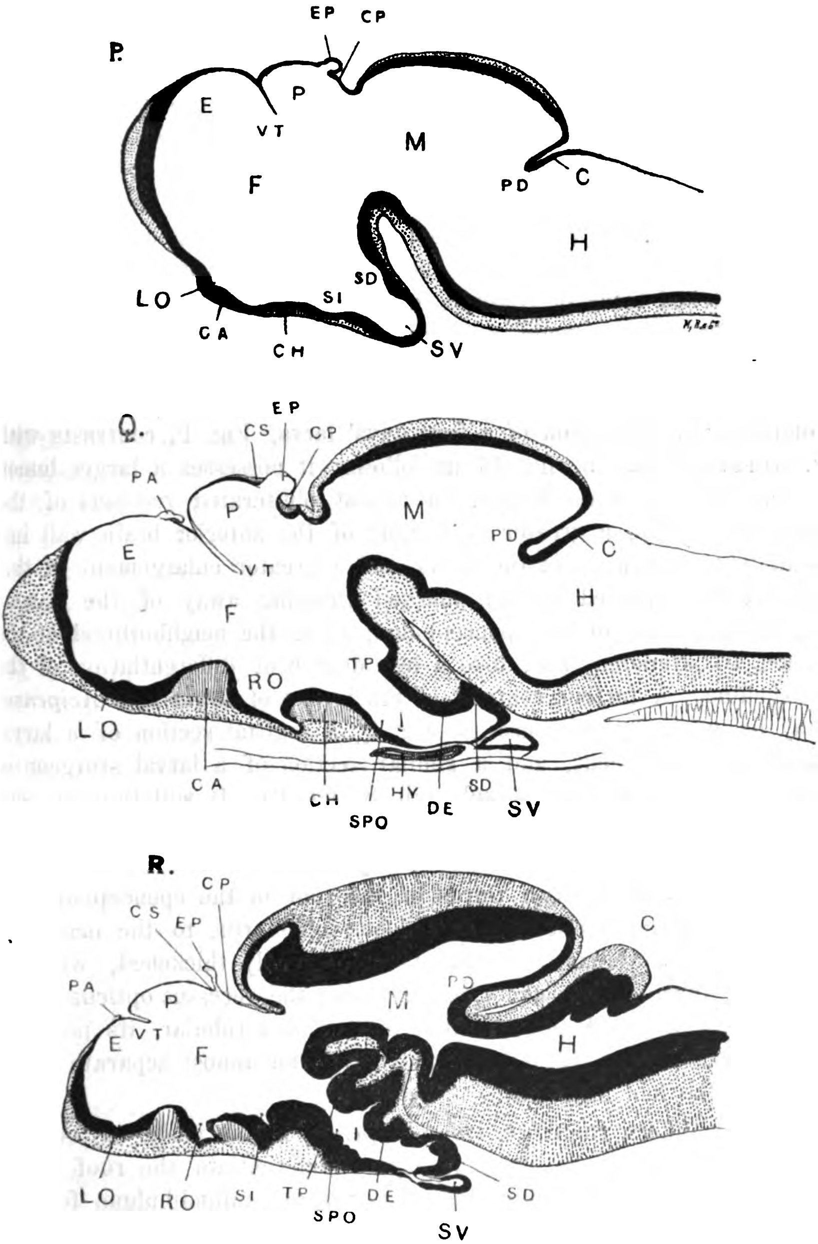
Little can here be added to the studies of JUNGERSEN on the pro- and mesonephros of larval *Amia*. The results of this author have been confirmed as far as the present observations have been carried. It has thus been found that 1) there are but two functional pronephric funnels at the time of hatching; 2) the segmental arrangement of the mesonephric tubules corresponds to that of the muscle plates; 3) the mesonephric tubules are not evaginations of the peritoneum, but are formed independently of it, in the neighborhood of the pronephric duct, into which they later establish their openings; 4) close relations exist between the larval excretory system of *Amia* and the Teleosts. The following is the only addition to the results of JUNGERSEN which can now be given. In the stage 24 hours before hatching the pronephric duct is relatively wider than that shown by JUNGERSEN in his first figure, and is lacking in snake-like twistings. The hinder portion of the duct is straight, its anterior division crook-shaped, bending inward and slightly downward. Its extreme tip opens into the body cavity through a loop-shaped perforation, the foremost (morphologically) pronephric funnel; a second opening is immediately behind (actually anterior to) it; and traces of a third immediately behind the second. By this is meant that the pronephric duct establishes temporarily a third connection with the coelomic wall, although the writer could not discover that a perforation subsequently occurred. This trace, however, seems noteworthy in view of the greater number of pronephric tubules of *Lepidosteus* and *Acipenser*. On the other hand the reduced number of the pronephric tubules is certainly of interest as a condition transitional to that of the Teleost.

e) Brain, neuromeres, hypophysis.

In the account of the early development the brain and spinal cord have been shown to have had their origin in a solid ectodermic thickening. In a late embryo, slightly earlier than that of Pl. 9, Fig. 1,



Figs. N—Q. Sagittal sections of brain of embryonic and larval *Amia*. Fig. R. Sagittal section of brain of *Salmo fario* at hatching. Fig. N of embryo surrounding about 195° of egg's circumference. Fig. O of larva at hatching. Fig. P of larva four days old. Fig. Q of larva four weeks old. *C* cerebellum, *CA* anterior commissure, *CH* chiasma, *CH'* notochord, *CP* posterior commissure, *CS* superior commissure, *DE* commissura debilis, *E* epencephalon (Kupffer), *EP* epiphysis, *F* forebrain, *FG* foregut, *H* hindbrain, *HY* hypophysis, *I* infundibulum, *LO* lobus olfactorius impar, *M* midbrain, *M'*



stomodaeum, *NM* neuromeres, *P* parencephalon, *PA* paraphysis, *PD* plica encephali dorsalis, *PV* plica encephali ventralis, *RO* recessus opticus, *S* larval sucking organ, *SD* sacculus dorsalis, *SI* sinus dorsalis, *SPO* sinus post-opticus, *SV* sacculus ventralis, *TP* tuberculum posterius, *VT* velum transversum.

the neural lumen has been fully acquired: the sagittal section of the brain at this stage, outlined in Fig. N, corresponds closely to that of a similar stage in *Acipenser*, as figured by v. Kupffer [1]) (tab. 4, 5, figs. 14, 15). It differs from the latter mainly in the flatness of the brain wall in the region of the recessus opticus, *RO*, and in the more down turned position of the lobus olfactorius impar, *LO*. By this stage in *Amia* the lobus has already been separated from the formative epiblast for (about) 10 hours, relatively at an earlier period, therefore, than in *Acipenser*. The sagittal section of the brain of a newly hatched larva of *Amia*, Fig. O, corresponds with v. Kupffer's tab. 6, fig. 17: its main differences include: a greater degree of flexure, a larger lumen anterior to the plica encephali ventralis, *PV*, a less degree of differentiation in the brain's ventral wall and in the commissures. A section of a four days' larva, Fig. P, contrasts with v. Kupffer's tab. 5, fig. 18 as follows: it possesses a larger lumen in the anterior brain region, an almost obliterated recessus of the lobus olfactorius, a greater thickening of the anterior brain wall immediately dorsalward of the lobus, and a greater enlargement of this region, accompanied by the marked thinning away of the parencephalon, *P*, and of the epencephalon, *E*, in the neighborhood of the velum transversum, *VT*; also a less degree of differentiation of the cerebellum. A further contrast of the brains of *Amia* and *Acipenser* may be made by reference to Fig. Q, a sagittal section of a larval *Amia* of four weeks, and a similar section of a larval sturgeon of the same age in v. Kupffer's tab. 8, fig. 19. It will thus be seen that in *Amia* have taken place by far the more striking changes, and that these have been confined largely to the anterior region of the brain. The anterior two thirds of the roof of the epencephalon (of v. Kupffer) (measured from the lobus olfactorius to the margin of the velum transversum) has thus become greatly thickened, while its posterior third has become ependymatous; the recessus opticus is now sharply pit-like, the infundibulum narrow and tubular, its posterior wall elongated, its sacculus ventralis, *SV*, an almost separate cavity (later of the lobi inferiores).

Amia differs, therefore, from *Acipenser* in the mode of its brain development mainly in its tendency to differentiate the roof of the epencephalon, and to reduce the caliber of the infundibulum, features

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1) Studien zur vergleichenden Entwicklungsgeschichte des Kopfes der Cranioten. Die Entwicklung des Kopfes von Acipenser, München 1893.

which are clearly interpretable as specialized. But on the other hand it should be noted that the brain of *Acipenser* is in some of its features more specialized than that of *Amia*, *e.g.*, in the high degree of differentiation of the cerebellum, of the commissures, of the velum transversum. The relation of the brain type of *Amia* to that of the Teleost, however, is clearly to be traced, the elaborately specialized brain parts of the latter readily reducing to the simple conditions of *Amia*. This relationship may best be understood by comparison of the brain shown in Fig. Q with that of Fig. R, a sagittal section of a newly hatched trout, *Salmo fario*. Similar parts are clearly recognizable, but the divergences which the structures of the bony fish have undergone in the line of differentiation are most noteworthy. Broad changes have befallen the mid- and hind-brain, and the region of the infundibulum: in the mid-brain the lumen has become notably reduced, its roof greatly enlarged, thick walled, massive, its floor convoluted in adaptation to its greater size: of the hind-brain the floor is heavily thickened, the cerebellum large and convoluted: the infundibulum is also deeply convoluted, and the sacculus ventralis is relatively enlarged. It is, accordingly, evident that the brain of the bony fish has increased enormously in size hindward of the chiasma. In front of the chiasma, on the other hand, its conditions have come to differ but little from those of *Amia*; the anterior flexure of the brain has become slightly more marked, the lobus now appearing as if in the middle of the floor of the epencephalon; the anterior thickening of the roof of the latter is no longer prominent, and its ependymal portion, if anything, smaller[1] in extent; the flattened roof of the parencephalon and the reduced depth of the velum transversum are finally to be noted as among the minor differences.

The foregoing comparison of the brains of *Amia* and a bony fish is not without a distinct phylogenetic interest: for it has shown that the transition between the Ganoid and the Teleost in these structural regards is by no means as broad as has been generally believed. That the brain arises as a solid ectodermal thickening instead of as a tubular organ formed in the beginning by the overgrowth of the medullary folds, is a feature common as well to some of the Ganoids (*Lepidosteus* and *Amia*) as to the Teleosts. Nor can any distinction be grounded on the epithelial character of the roof of the Teleostean forebrain, for precisely similar characters have been shown to occur in *Amia.* It is further evident that the brain of the bony fish is so closely Amioid that it may reasonably be looked upon as but a high degree of specialization of this neo-ganoidean type. The development of the brain of the Teleost is fully in keeping with the precocious growth rate of its other structures: by the time of hatching the brain, Fig. R, has assumed far more nearly its adult characters than has that of a month old *Amia*, Fig. Q.

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[1] In subsequent stages the ependymal portion becomes relatively larger.

The subject of the roof of the forebrain deserves a final word, especially in view of the unorthodox position of BEARD [1]). For, according to this writer, the pallium of lamprey and Teleostome was the homologue of the choroidal plexus of shark, lung-fish and amphibian; and it was, accordingly, taken as a most important character to separate two phyla of fishes. That this position is untenable is now evident from the studies of BURCKHARDT on the forebrain of fishes, especially as to the increase in its ependymal region, in which are traced well marked transitions from Selachian to Teleostean conditions. The results of BURCKHARDT [2]) are further confirmed by the study of the mode of development of the forebrain among the three types of Ganoids; for in these, as in a graded series, it may be shown that the ependymal region increases in size as the more modern type, *Amia*, is attained.

Neuromeres.

The recent memoir of LOCY [3]) has directed renewed attention to this subject. In *Amia* the discussion of neuromeres belongs more strictly to the period of later embryonic development and will not therefore be included in the present paper. Note should be made, however, of the very prominent neuromeres which appear in the floor of the hind brain, beginning immediately on either side of the sagittal plane, in the stages figured in Pl. 9, Figs. 1—7. These may be seen in the section of Fig. N, in which the hind brain has been cut in a favorable plane: five neuromeres are shown, the middle one the most prominent, the fore- and hindmost ones fading away into the region of the plica ventralis and cord respectively. Similar conditions, but not so favorably shown, have been seen by the writer in *Acipenser*, *Lepidosteus* and *Amiurus*, and they have also been noted in *Fundulus* by Dr. O. L. Strong.

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[1]) On the interrelationships of the Ichthyopsida, in: Anat. Anz., V. 5, 1890, p. 146—159.

[2]) in: Anat. Anz., V. 9, No. 12, p. 375—382.

[3]) in: J. Morph., V. 11, 1895, No. 3, p. 497—594.

Hypophysis.

The hypophysis is by no means as important an element in the development of the head in *Amia* as in the other Ganoids. Its appearance is late and inconspicuous. It has not been found in stages earlier than that of Fig. O, and even here its presence is not definite: at the most the position of its lumen can be recognized as the line, *HY*, formed by the arrangement of cells immediately below the region of the recessus opticus. These cells are apparently ectodermal for they are arranged in a continuous line with the cells of the formative epiblast of the dorsal wall of the stomodeum, but on the other hand their ventral limit cannot be distinguished from the entodermal cells roofing the foregut, *FG*. The tissue of the region of the hypophysis in *Amia* we may therefore conclude, has been brought into its definitive position at a relatively precocious period, and accordingly it has followed that abbreviated ontogeny has suppressed many phylogenetic stages. Thus the present writer has been unable to find that the hypophysis has at any time established an outer opening or in fact any fusion with the mouth roof: its wall has been entirely differentiated in situ, and its slender lumen formed. Its condition in a larva of one month is shown in Fig. Q at *HY*. The hypophysis of *Amia* will accordingly be seen to present well marked transitional features to that of the bony fishes.

f) Sense organs, sucking disc, ciliation.

The mode of development of the eye and of the nasal and olfactory capsules differs but little from that typical in the lower vertebrates generally. As already noted by Allis the nasal capsules, in their early stages, are connected with and closely correspond to the neighboring sensory pits of the mucous canal system. But on the other hand there appears to be no evidence that the auditory sac in *Amia* arises as in the Teleost *Serranus*. Here, according to H. V. Wilson, a common sensory furrow is the Anlage of the ear, the branchial sense organ, and the lateral line, — a condition which has been generally accepted as demonstrating a close genetic affinity in these associated structures. And close their affinity doubtless is, although the present writer cannot regard the evidence of *Serranus* as of undoubted phylogenetic value. For the process of shortening phylogenetic stages in the ontogeny of a bony fish has evidently progressed to such a degree that the ancestral relations of epiblastic organs might have become greatly obscured by the processes of precocious growth. To regard the evidence of the common sensory Anlage in *Serranus* as final and satisfactory evidence of the genetic kinship of these structures would, in the opinion of the present writer, be scarcely more conclusive than the homologizing of hypophysis and teeth on the ground of their having arisen in ***Amia*** as more or less solid structures in the epiblastic roof of the mouth.

Sucking disc.

The mode of origin of the sucking disc gives the most interesting evidence of how precociously embryonic and larval structures may be developed. As far as histological evidence goes there is certainly no difference between the enlarged thick-walled cup-shaped organs which arise on the snout of the late embryos of ***Amia*** or of ***Lepidosteus***, and the typical pit organs, or sense buds, which later occur on other integumental regions. It is found in fact that a gradation in size exists which connects the huge sucking organs of the snout [1]) with the inconspicuous pit organs of the trunk. It is certain that these sucking organs, whether in the condition of little differentiated Haftscheibe (*Acipenser*), scattered sucking hillocks (*Lepidosteus*), or in groups as ring-shaped lobes (*Amia*), are purely larval structures, and that they occur (probably) only in Ganoids. They have evidently no place in the general study of the vertebrate head. But humble as their morphological rôle may be they yet throw a strong side light on the mode of evolution of structures not merely of the vertebrate head but of the entire vertebrate organism. For if a process of evolution can be made for so transient a purpose to produce sense buds in a definite locality enormously enlarged, and at a very early period, earlier not only than their kindred structures but even earlier than mouth, nose, liver, fins, gill slits, a similar process of evolution can even as evidently cause such sense organs as the nose, ear and eye to appear precociously in a definite region and in such enlarged and perfected form as to mask their genetic kinships. So too could brain parts or cranial nerves be precociously evolved, so that even at their earliest stages they would give no definite clue as to their ancient form or relationships. And in like manner in the trunk region might the same principle be applied; thus at a definite point on the trunk wall could be produced fin structures at once large and perfected[1]) whose entire mode of growth should give little evidence of recapitulation.

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[1]) There is but little difference histologically between these and the neighboring nasal pits.

Ciliation.

The ciliation of the body of the Amphibians, as recently described by ASSHETON[2]), does not appear to find a parallel among larval Ganoids. The present writer has been unable to find in *Amia* any tracts of ciliated epithelium other than those which form the mucous canals. The present observations, however, were made entirely upon preserved material, but this it may be noted was so favorably preserved that the cilia of the sensory canal regions and of the gut were clearly distinguished.

IV. Conclusions.

From palaeontological studies there can be little doubt that a series of transitional forms, closely Amioid, included in the families *Eugnathidae, Amiidae, Pachycormidae, Pholidophoridae* and *Leptolepidae*, provide the actual stepping stones from the Ganoids to the Clupeoid Teleosts. And as this genetic relationship of the Teleosts is now coming to be widely recognized it becomes less important to harmonize differences between the later and the older groups on the side of their embryonic and larval development. In the ontogeny of *Amia*, however, can now be found the final evidence of this genetic kinship — to serve both to confirm the palaeontological results, and to cause these to be accepted unhesitatingly by the embryologist. In the early stages of development the nearnesses of *Amia* to the Teleosts have already been shown, and in the present paper the larval stages of these forms have been found to possess many striking similarities, as in the development of the hinder digestive tract, post-anal gut, unformed neurenteric canal, hinder excretory ducts, liver and yolk, pronephros, brain, neuromeres, hypophysis.

But the especially suggestive feature which a study of the larvae of *Amia* has brought out is the matter of precocious development. We find, for example, that the organogeny of *Amia* progresses more

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1) As in *Ceratodus*, as figured by SEMON.

2) in: Quart. J. Micr. Sc., V. 38, 1896, Part 4, p. 465—484.

rapidly than in *Lepidosteus*, yet not nearly as rapidly as in the Teleost. The shortening in the duration of the larval period, of which the transitional *Amia* provides so interesting an example, is clearly a developmental result which could hardly have been suggested on a priori grounds. For it certainly seems far more consistent with our preconceived ideas that the development of the older and simpler forms[1]) should be briefer than that of the forms derived from them: but in this case (*Amia*) we are given a well marked instance that the later forms have become specialized in the acquisition not merely of adult characters, but of developmental processes as well; that they have tended in their evolution to acquire their adult characters at an earlier period, to elaborate their conditions of yolk nutriment so that the growth processes might be shortened, and that the larva should more speedily be rendered self maintaining and self protecting. The shortening of the developmental, especially the larval period in the more recent forms, appears to bring with it a further and most interesting feature: for the shortening of the growth processes has produced a need for masking the stages of transformation. It would thus seem that a directive energy were making itself felt within tissues apparently undifferentiated, and giving them their definitive uses, long before they could have had the time to have performed even a part of the changes through which in phylogeny they have passed.

A comparison of the larvae of the Ganoids and Teleosts, Siluroids especially, brings to light with surprising clearness how perfect a range they present in transitional characters. Taking into account the forms of the early larvae, pigmentation, mouth and anus, gill characters, opercula, fin differentiation, yolk absorption, brain and sensory structures, all of these different types may readily be arranged in a gradational series. At the base of this series stands *Lepidosteus*, near it and in some ways even below it is *Acipenser*, next is *Amia*, next, and very closely related, is *Amiurus*, and finally are the many remaining forms of Teleosts.

Zoological Laboratory of Columbia College,
New York City, April 21, 1896.

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1) In spite of the fact that among fishes it has generally been recognized that the shark's period of immaturity is longer than the lung fish's, the lung fish's than the Ganoid's, the Ganoid's than the Teleost's. This time relation might readily prove a caenogenetic one, dependent, for example, on richer yolk-supply.

Explanation of Plates.

Plate 9.

All figures of this plate have been drawn by the author from living material.

Fig. 1. Late embryo, surrounding about 200° of egg's circumference. 138 hours. × about 20.

Fig. 2. Late embryo, surrounding about 225° of egg's circumference. 142 hours.

Fig. 3. Late embryo of Fig. 2, shown in a somewhat ventral aspect.

Fig. 4. Late embryo, surrounding about 240° of egg's circumference. 148 hours. × about 18.

Fig. 5. Very late embryo, surrounding about 290° of eggs circumference. 160 hours. × about 20.

Fig. 6. Larva about time of hatching. 180 hours.
Fig. 7. Larva of Fig. 6,. shown in dorsal aspect.
Fig. 8. Larva of about the beginning of the second day.
Fig. 9. Larva of about the middle of the third day.
Fig. 10. Larva of the fourth day. × 19.
Fig. 11. „ „ „ „ „ Dorsal aspect.
Fig. 12. „ „ „ „ „ Ventral aspect.
Fig. 13. Larva of the fifth day. × 16.
Fig. 14. „ „ „ „ „ Dorsal aspect.

au auditory sac, *gs* gill slit, *h* heart, *i* intestine, *l* liver, *ll* lateral line, *m* mouth, *n* nasal pit, *o* opercular dermal fold, *ol* optic lobes, *p* pericardium, *pc* post-cardinal (caudal) vein, *pf* pronephric duct, *pr* proctodaeum, *pz* parietal zone, *sd* sucking disc, *si* subintestinal vein.

Plate 10.

Figures 15—19a drawn from the living larvae.

Fig. 15. Larva of the sixth day. × 16.
Fig. 15a. „ „ „ „ „ Distal view of sucking disc.
Fig. 16. „ „ „ „ „ Dorsal aspect.
Fig. 17. Larva of the eighth day. × 16.
Fig. 18. „ „ „ „ „ Dorsal aspect.
Fig. 19. Larva of the tenth day. × 14.
Fig. 19a. „ „ „ „ „ Jugular region.
Fig. 19b. „ „ „ „ „ Sucking disc.

Fig. 20. Larva of about the fifteenth day. × 12.
Fig. 21. „ „ „ „ „ „ Ventral aspect.

a anal fin, *an* anterior naris, *ant. an.* anterior anal fin, *b* basal fin support, *brs* branchiostegal rays, *c* caudal fin, *ch* ceratohyal, *jug.* jugular plate, *o* operculum, *pn* posterior naris, *r* radial fin support, *v* ventral fin.

Plate 11.

Fig. 22. Larva of about the twenty-second day. × 7.
Fig. 23. „ „ „ „ „ „ Dorsal aspect.
Fig. 24. „ „ „ „ „ „ Ventral aspect.
Fig. 25. Larva of about the thirty-fifth day. × 7.
Fig. 26. „ „ „ „ „ „ Ventral aspect.

a anal fin, *an* anterior naris, *ant. an* anterior anal fin, *ao* anal opening, *brs* branchiostegal rays, *c* caudal fin, *c-a* membranous fin connecting caudal and anal, *dr* dermal fin rays, *io* interoperculum, *jug.* jugular plate, *la* linea alba, *o* operculum, *p* pectoral fin, *pn* posterior narial opening, *r* radial fin supports, *so* suboperculum, *ug* urinogenital eminence, *v* ventricle.

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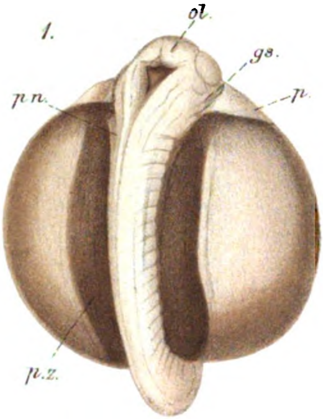

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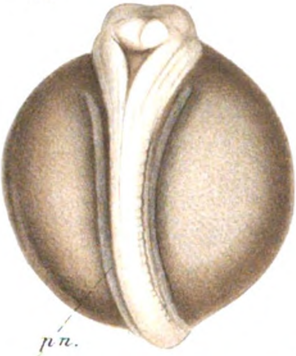

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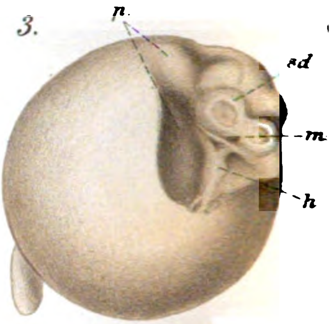

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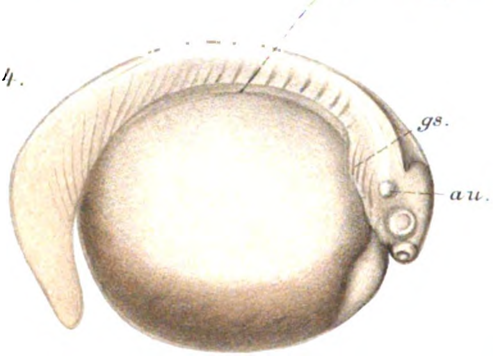

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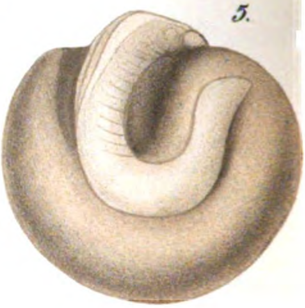

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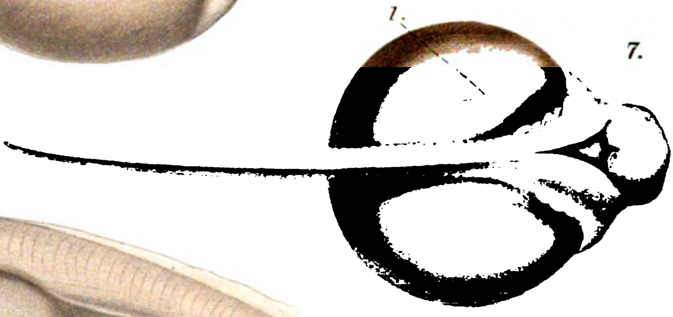

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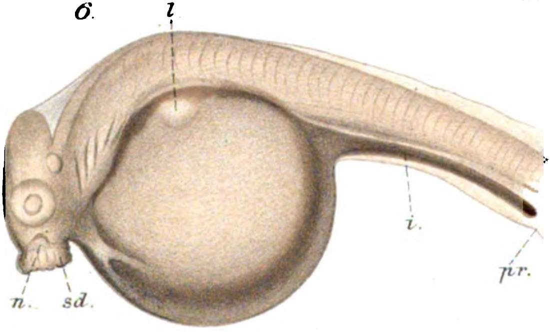

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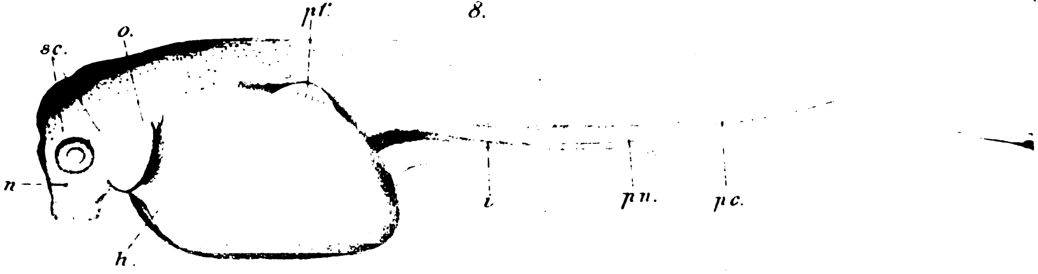

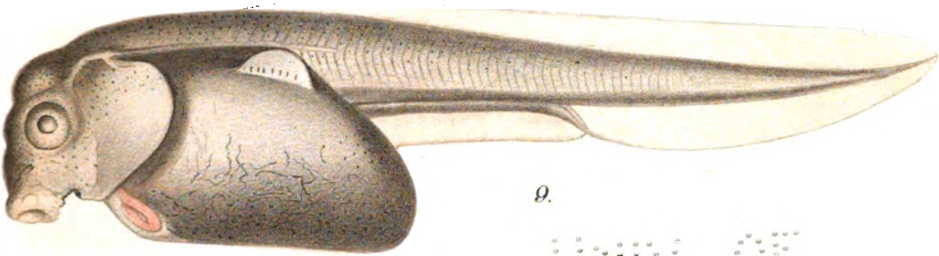

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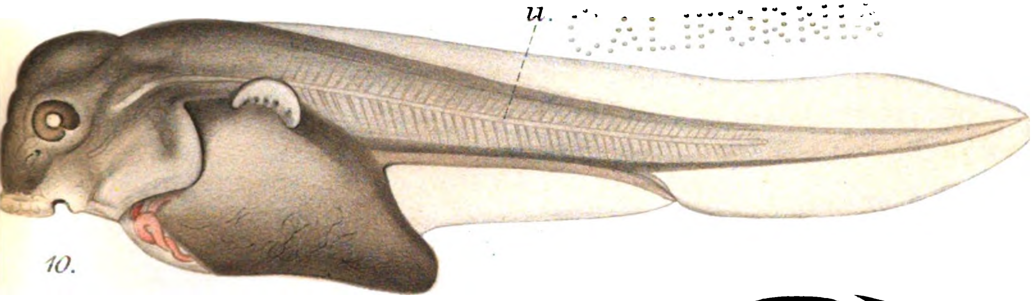

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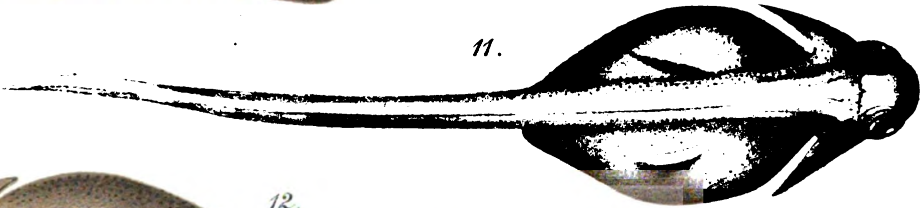

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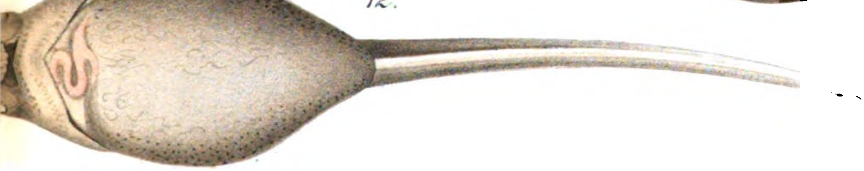

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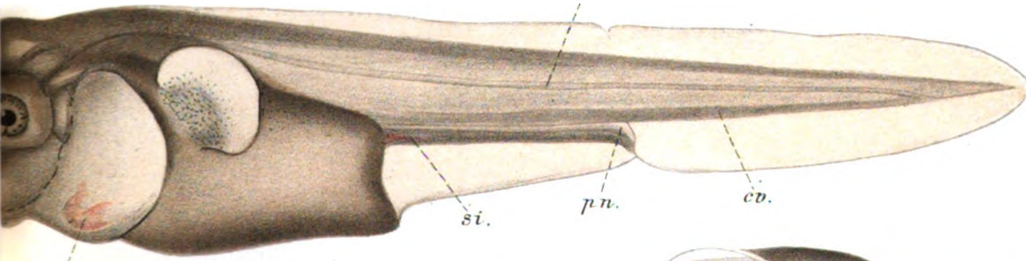

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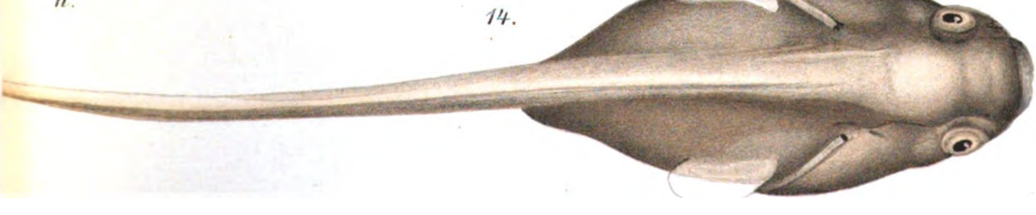

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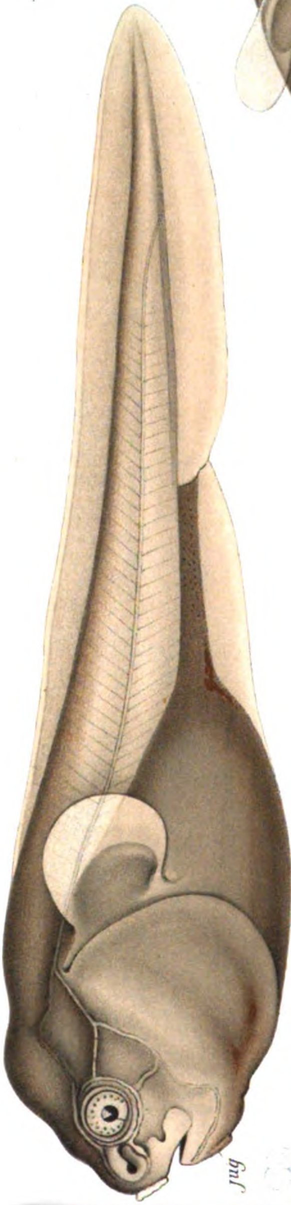

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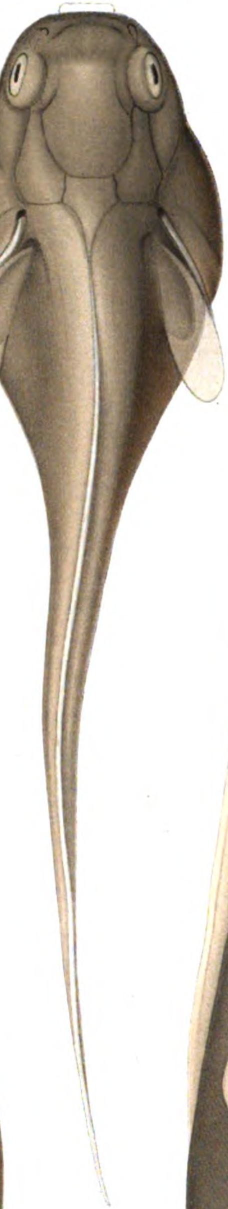

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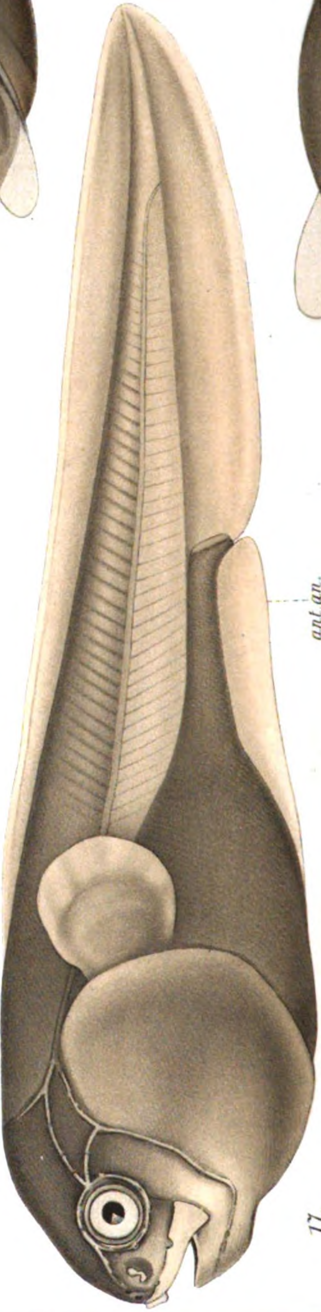

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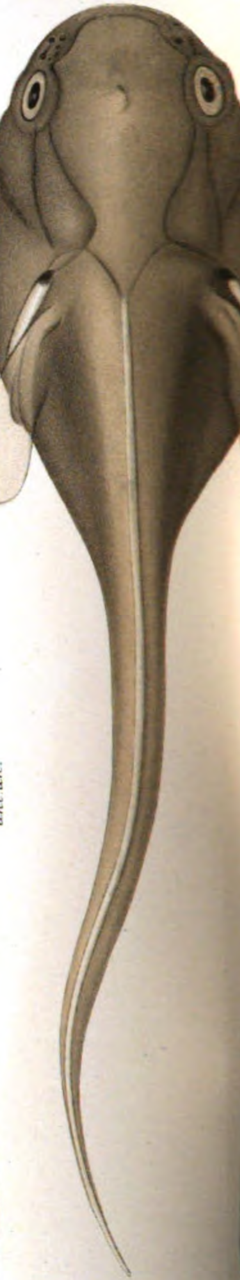

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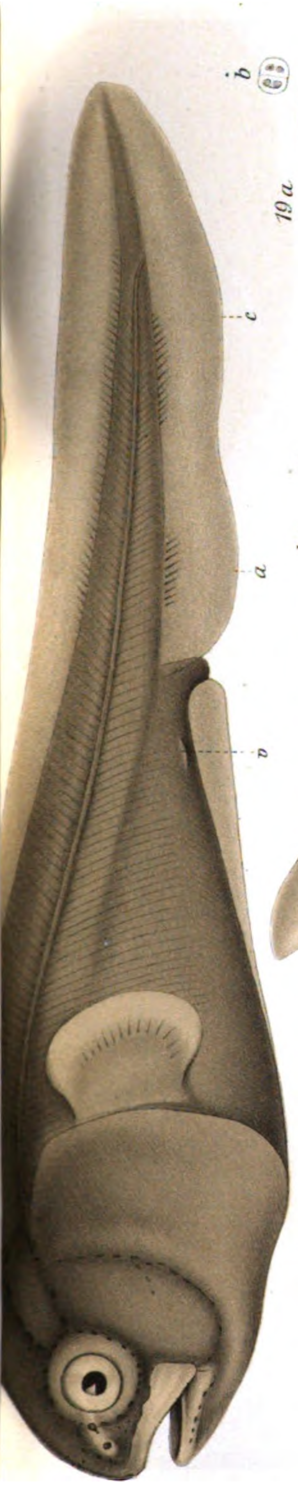

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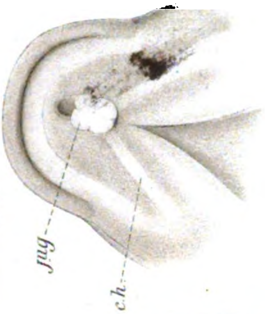

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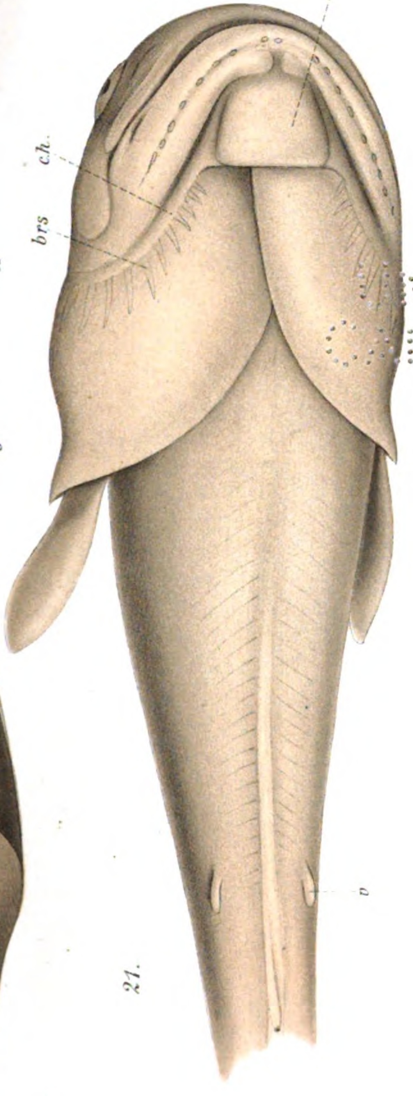

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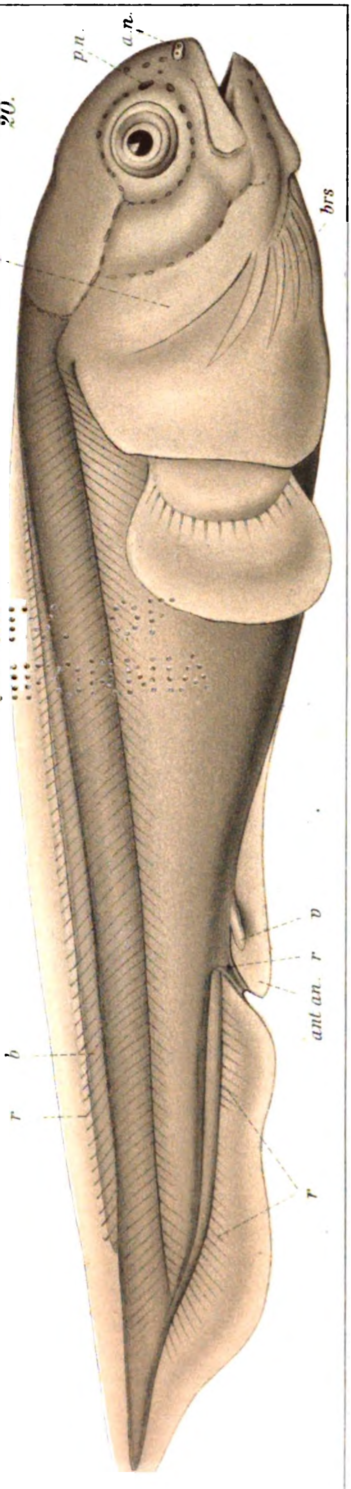

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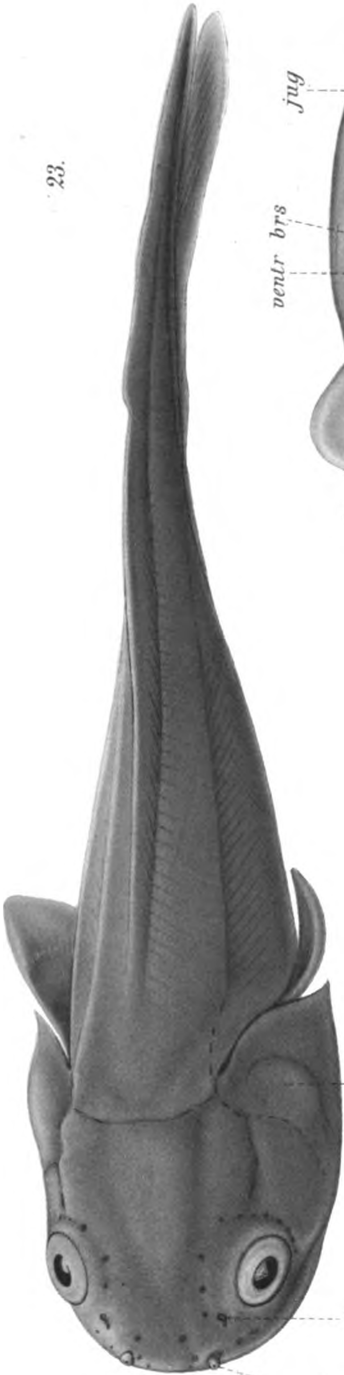
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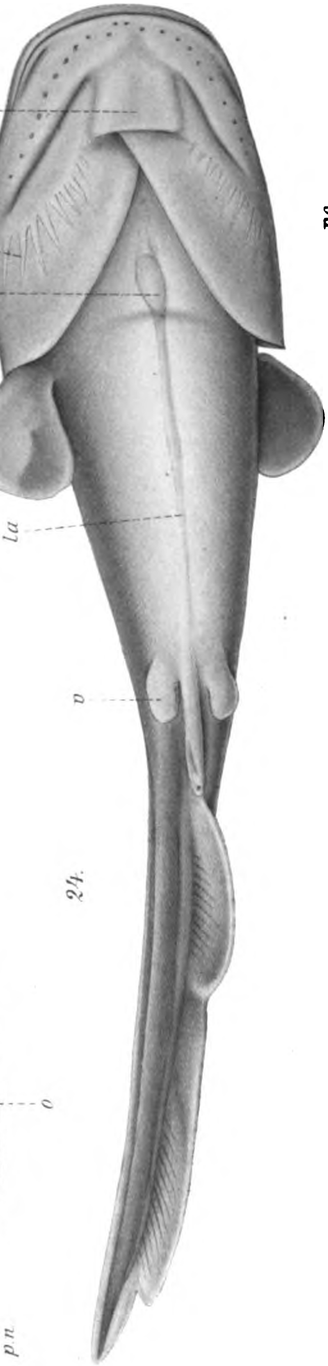
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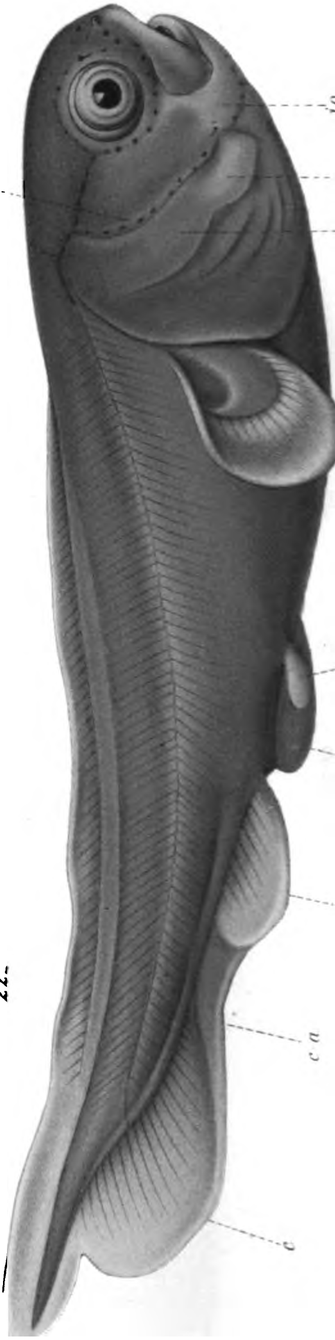
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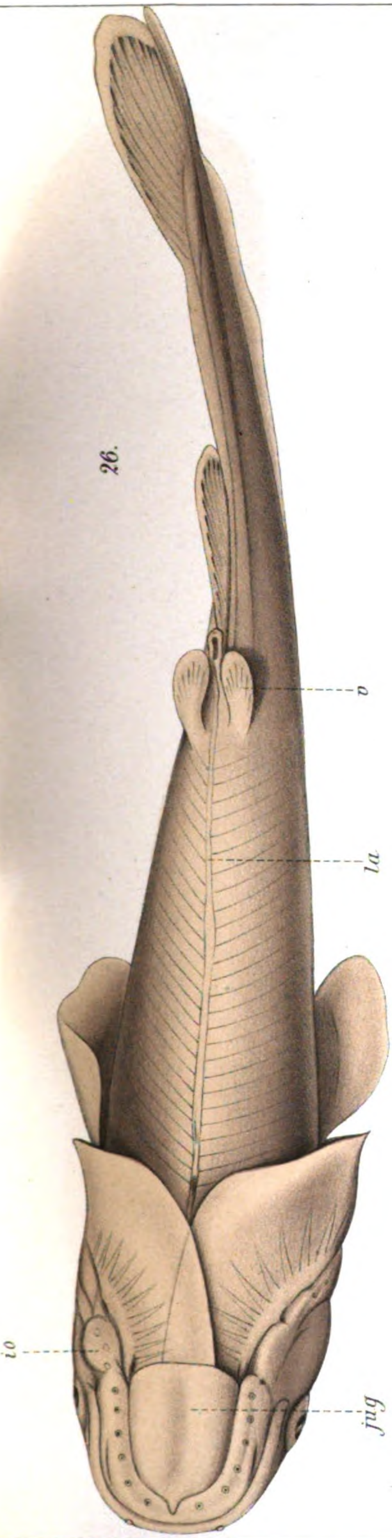

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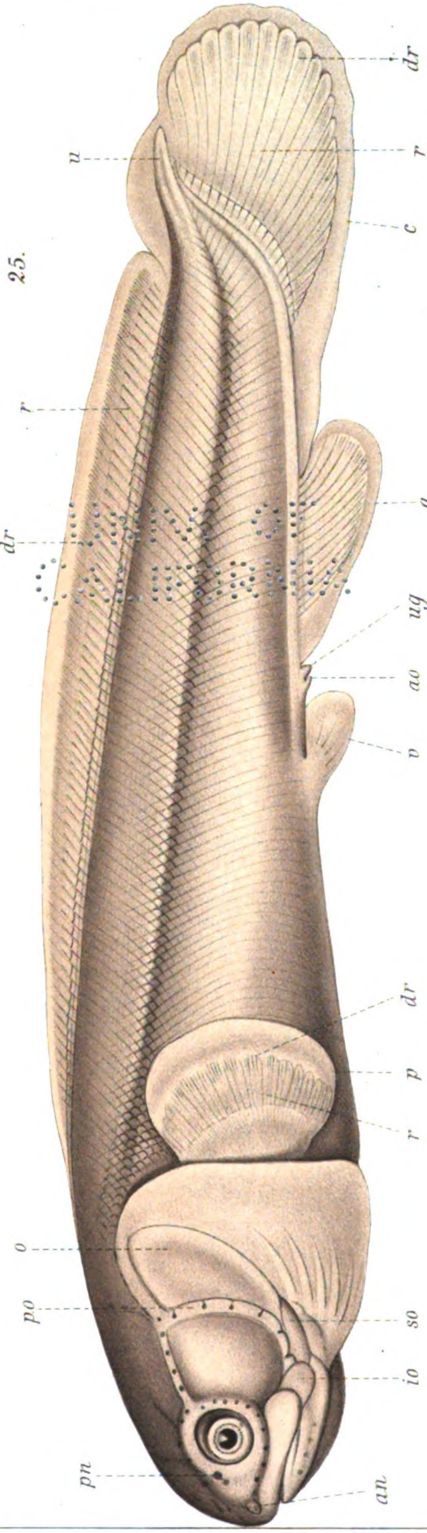

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Reprinted from "NATURAL SCIENCE," Vol. XI., No. 65, July 1897.

With the Compliments
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9

A CALIFORNIAN MARINE BIOLOGICAL STATION.

(ILLUSTRATED)

BY

BASHFORD DEAN, Ph.D.

Printed by Turnbull & Spears, Edinburgh.

II.

A Californian Marine Biological Station.

THE European zoologist who visited the Pacific states would be very apt to find his way to the old Spanish-Californian town of Monterey, and to the Marine Laboratory of the Leland Stanford Junior University. As this station, however, seems to the present writer surprisingly little known in proportion to its deserts, a brief account of its equipment and surroundings may prove of interest to the readers of *Natural Science.*

This at the present time is the only permanent biological station on the American side of the Pacific. Temporary stations have indeed been established within recent years. The University of California has several times carried on a seaside school of zoology, both at Pacific Grove near Monterey, and on the Santa Catalina Islands in the region of Santa Barbara. Further northward, in Puget Sound, Washington, a local society, that of the Young Naturalists of Seattle, has done excellent faunal work during its camping seasons; and in the same region during last summer Columbia University of New York established a laboratory at Port Townsend.

The Stanford, or the Hopkins Laboratory, as it is called, is both an annexe and an integral part of its university. It was, indeed, contemplated as early as the time of the building of the university, when it was decided that a portion of the studies in zoology and botany might be carried on during the summer, the students to be given the regular credit for their work as in the winter courses. It was, accordingly, with a summer laboratory in view, that in 1891 two of the Stanford professors, Drs O. P. Jenkins and C. H. Gilbert, visited the region of Monterey (which had indeed been known to Dr Gilbert previously during his studies on the fishes of the Pacific), and made a reconnaissance to determine the particular point of the bay which was best suited to the needs of the collector and investigator. The site they then determined upon was at Pacific Grove, a few miles westward of Monterey. Here, in the first place were found most favourable fields for collecting. The shores were unshifting, the coast was rugged, while huge rock masses and bluffs alternated with sheltered harbours and beaches, rich in forms of animals and seaweed life. The locality seemed also a particularly convenient one on account of its facilities for the lodging and living of students, a summer settlement of possibly five hundred people being in the immediate neighbourhood. It was here finally that land was obtained, a gift of the Pacific Grove Improvement Company, and the buildings were shortly put up and equipped, thanks to the generosity of Mr Timothy Hopkins, after whom the laboratory has been named.

The buildings are shown in the adjoining figure (Fig. 1), but the picture gives only a slight idea of their surroundings; thus they are seen to be built on a level field, and there is but a glimpse of the sea in the background. One needs, therefore, to imagine the laboratory site as a small treeless plateau, on the top of an abrupt rocky point which terminates about a hundred yards to the right in the picture. The sea surrounds the buildings, therefore, on three sides. In front there is a sheltered harbour and a small sandy beach, furnishing an admirable landing place for the boats; at the back the surf is breaking on the rocks thirty feet below—hardly far enough away as it has been proved, for in the winter storms the waves have threatened to overturn the buildings, and have rendered necessary the additional braces which one sees at the corners of the building. From its position the laboratory becomes a prominent feature of the entire neighbourhood. The visitor will not fail to notice it even at the incoming of his train, for he naturally will be looking seaward after his three hours' journey from San Francisco. He will just have passed through the hot and dusty valley country, but his interest revives as the train emerges on the sea-coast at Monterey, thence to skirt the shore of the bay during the few final minutes of the trip.

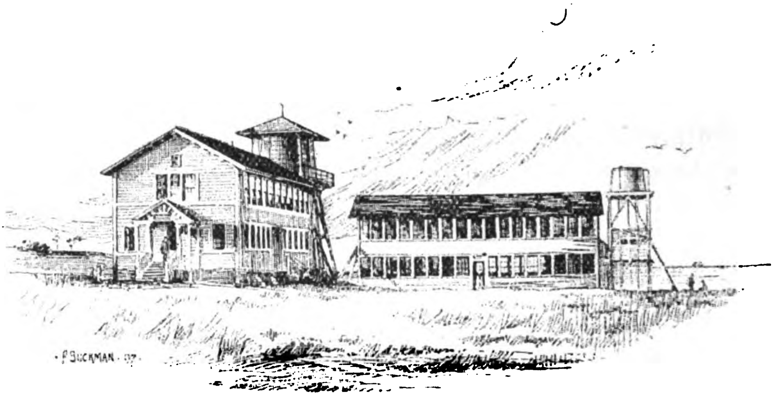

Fig. 1.—The Hopkins Seaside Laboratory, near Monterey, California. East view.[*]

The bay of Monterey appears not unlike that of Naples. There is the same long curving beach, broken with rocky points, the clear blue water, and the same setting of half tropical vegetation, although the mountainous background is lacking. The climate is here less variable than at Naples; the temperature remains almost constant throughout the year, each day averaging about 60°F., and during six of the months outdoor life is not interrupted by rain. The railroad line terminates at Pacific Grove. Here on one side of the railroad are bluffs and the rocky point on which the laboratory is situated, while on the other a tidy little town, with well kept villas, bright shops, lines of tents for the summer campers, a good hotel, and a small park-like square, rich in the deep greens and light olives of Californian plants. All about are scattered forest trees—live oaks, tall pines, eucalyptus and palms. With these are numerous trees and hedges of the Monterey cypress (*C. macrocarpa*), whose very restricted range gives it an especial interest.

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[*] The illustrations have been prepared by Mr Percy Buckman from photographs taken by the author.

Point Aulon, the little promontory on which the laboratory is situated, juts out from the western end of the town. It has been fenced off as a kind of marine park for the cottagers; and here at all times throughout the summer may be seen clusters of people, old and young, idling away their holidays, clambering about the rocks, or watching the ceaseless strings of cormorants, or the doings of the little school of boats huddled closely together off the point salmon catching, or the return of the little fleet of Chinese fishermen, whose curious town may be seen on a projecting coast point in the direction of Monterey. Such a thing as the sight of an occasional whale or sea-lion, and these will come surprisingly near the point, or even the loss of a straw hat, will cause a flutter of excitement among the summer visitors, diverting their attention, as a student will uncharitably believe, from their attempts to invade the penetralia of the laboratory.

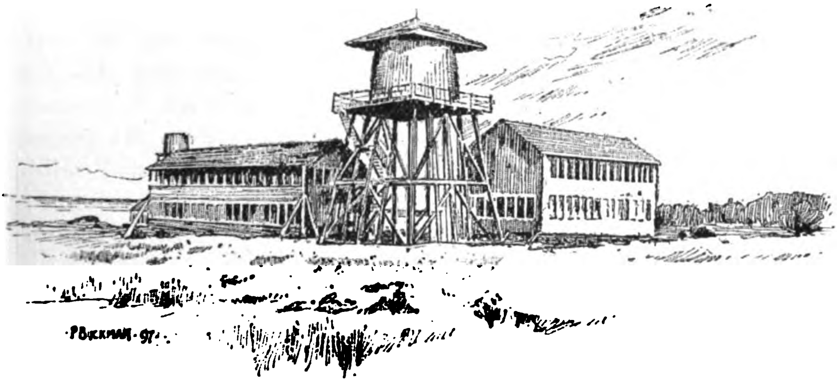

FIG. 2.—The Hopkins Laboratory. West view.

Our second illustration (Fig. 2) gives a west view of the two buildings. The older, used during the first and second sessions of the summer school in 1892 and 1893, stands to the left, long, and with many windows. It measures sixty feet long by twenty feet wide. The newer, smaller, but more substantial building measures forty by twenty-six feet. From the figure one may also see the two large salt-water tanks, which have been so arranged that each can supply either building. The older building is now used mainly for the classes of elementary students. It has two laboratories on the ground floor, a small engine room, and a concreted workshop, which serves as a dissecting room for the larger marine beasts. Upstairs a long laboratory faces the east, and on the south side a series of small separate rooms have been arranged for investigators. In the newer building a laboratory occupies the rear end of the ground floor, used during last summer mainly for students in the botanical courses; and on the floor just above there is a room of the same size, with blackboards, cases, and portable tables, used both as a lecture room and laboratory. The front part of the house in both storeys is divided by partitions into a dozen rooms for investigators, and it has, in addition, a photographic dark room. Throughout both buildings the fittings are simple but adequate. There is an abundant supply of microscopes, reagents, glassware and the usual set of dredges, tangles, and nets, a small beam-trawl, and apparatus for sounding and temperature-taking. At present the boat facilities include only a rowing boat and a small sailing boat, the latter almost too small for dredging or trawling, except in comparatively shallow water. Hitherto, however, the laboratory seems scarcely to have needed collecting facilities for the deeper water—enough at least to warrant the support of a steam vessel. The shore fauna has been of the richest, and dredging in shallow water could well be done with the boat at hand. As a convenient means of collecting in the shallow rocky bays a water-glass has been found of great service, especially in securing conspicuous forms such as echinoderms and holothurians, and has to a certain degree served as a substitute for diving apparatus, which here, as at the French marine station at Banyuls, might well prove of the greatest value. The station has never found difficulty in securing an abundant supply of fish material, thanks to the Chinese fishermen of the neighbouring village.

A whole article might be written on this small Chinese village near Monterey. It is but a quarter of an hour's walk from the laboratory, approached along the ledge of the railroad on the seaside rim of the town—a daily walk for a number of the students, who have come to have the greatest faith in the fishing powers of the heathen. This walk is by no means an uninteresting one; the sea-birds are around, whitening the tall rocky ledges, and on every hand there are quantities of little ground squirrels—a species of spermophile—which sit up before the visitor like little prairie dogs.

The village itself looks as though it has been imported from China in its present condition, a huddled little town of unpainted shanties sprinkled closely along a crowded street, with a few shops, a joss-house, and a sky-line of picturesque scaffolding for fish-drying. There will be a crowd of mushroom-hatted fishermen, a din of chaffering, a mixture of nets, trawl lines and baskets, distinctly unpleasant odours, placards of crimson and tinsel spattered with Chinese characters. The people are Cantonese, many of whom have been living here for two generations. They are classed as a peculiar poor grade of Chinaman, and are, I am told, looked upon at home as mere barbarians, if for no better reasons, that they have lived in China only two or three centuries, and are unable to trace their descent for more than seven generations. To the stranger, however, they certainly appear very industrious, honest (except in bargaining), kindly and painstaking. They are excellent fishermen, and in several instances very intelligent collectors. Their little fleet of boats is often out before sunrise; between seven and ten they have become scattered along the coast, and their trawl lines are put out, often six or more (each about five-eighths of a mile long) to a boat; about noon-time they return, their skiffs sometimes gunwale-deep with fish-rock cod, black bass, flounders, mackerel, with an occasional wolf-fish,[1] their little latteen sails making the picture a still more foreign one. In a few moments after landing, the fish are carried off in shoulder baskets, to be shipped to San Francisco, and the boats are drawn high up on the beach (Fig. 3). The little colony also carries on a very successful squid-catching industry, so that at night there is often as much life and excitement in Chinatown as during the day. The amount of a catch will often be measured by tons.

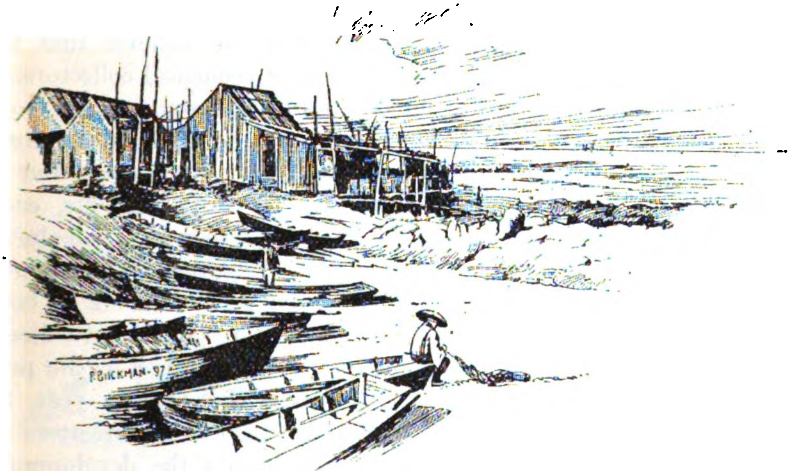

FIG. 3.—The Chinese Fishing Village at Monterey. A corner of the beach.

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[1] *Sebastodes* (*nebulosus*) and *melanops*, *Scomber* (*colias*), *Platichthys*, *Anarrhichthys*.

The boats go out with nets and red pine fires, which are hung cressetwise over the sides of the boats to lure the squid. Some of these are intended to be cleaned and dried on latticed trays as a staple article of diet in Chinese markets. The bulk of the catch is, however, spread over the fields for drying, then to be packed in matting bags for export to China, as a rich fertilizer for the rice fields. Another phase of their industry is that of collecting abalones, *Haliotis*, these also to be dried for export. The people have their usual Oriental thrift,—they are infamous at a bargain, but make up this deficiency by the skill with which they separate the fertile or unfertile eggs of sharks or *Bdellostoma*, and recognise what they refer to as the 'hen' or 'rooster' sharks or rat-fish (*Chimaera*).

There is also another little imported village in this neighbourhood, nearer Monterey, namely, a settlement of Portuguese, who, like the Chinese, have retained minutely their foreign ways. Their boats are precisely those one would see in the Tagus, and, judging from the writer's experience in Portugal, he believes that the immigrants have not improved in the way of zoological collectors.

The laboratory has now completed its fifth season, and the work of last year seems to have been carried on very much in the lines of former years. There is a class in the dissection of types, and in the study of methods, limited to twenty or thirty students, each paying a stated fee for a term of six weeks. A second class includes advanced students in zoology, mainly from Palo Alto. The investigators, finally to be mentioned, occupy the private rooms in both buildings. These are afforded their quarters, reagents, and collecting facilities gratuitously. Class instruction is carried on by the professors of the Stanford University, during the present year by Doctors Jenkins, Shaw, and Wilbur. Among the investigators of the past summer were W. R. Shaw, working on the development of conifers, E. P. Wheeler, on the embryology of *Dicyema* and on diptera, D. A. Saunders, on the brown seaweeds, H. Heath, on the anatomy and development of *Chiton*, O. P. Jenkins, on contractility of muscles and conductivity of nerve-tissues in invertebrates, H. P. Johnson, on the annelids, and W. E. Ritter, on the ascidians, W. A. Setchell, on (laminarian) seaweeds, and the present writer, on the development of *Chimaera* and *Bdellostoma*. Many of these investigators have previously spent summers at the laboratory. Among the workers of former seasons might be mentioned H. Ayers, whose lecture on *Bdellostoma*, published in the volume of zoological lectures of Wood's Holl Laboratory (1893), has merited wide attention. Dr C. H. Gilbert, as the director of the station jointly with Dr Jenkins, has also been a constant visitor, and has here prepared no little part of his studies on the ichthyology of the Pacific. Dr E. C. Price, also one of the zoological staff at Palo Alto, was the first of the several workers at the laboratory to secure embryos of *Bdellostoma;* while on the botanical side F. M. M'Farland and L. H. Campbell have been in frequent attendance. President Jordan has also taken the warmest personal interest in the work of the station, and although his researches have hardly been carried on at Pacific Grove, he has, nevertheless, been a constant visitor.

It is evident, perhaps, from the foregoing pages that the zoological station of the Stanford University has neither the equipment nor the subsidies of the Stazione at Naples, or even, as yet, of the laboratory at Wood's Holl; but the zoologist will certainly find there all of the facilities for his work which can reasonably be needed. The warm interest which Dr. Jenkins has shewn in the welfare of each worker of the station will not be forgotten; and it is doubtless due in no small degree to this care that the visitor takes away with him the kindliest recollections of Stanford's hospitality. The richness of the fauna and flora of this little nook in the Pacific cannot fail to leave the strongest impression upon the visitor's mind. He will remember the rugged shore line, with its stunted and twisted cypresses (Fig. 4), the sunken rocks bristling with the largest sea-urchins, the bright-coloured star-fishes, the orange-red *Cucumaria*, a yard in length. So too the tidal rocks covered with *Pollicipes,* the clumps of palm-tree-shaped *Postelsia,* the tangled masses of bull-kelp (*Nereocystis luteana*), whose stems are often many fathoms in length; the field-like areas of *Macrocystis* (*M. pyrifera*); the rich molluscan fauna, including the red shelled *Haliotis,* to be found even at the base of the laboratory rocks, *Cryptochiton* (*C. stelleri*) seven inches long, and abundant nudibranchs. There is a wealth of ascidians, annelids and hydroids. Nor does

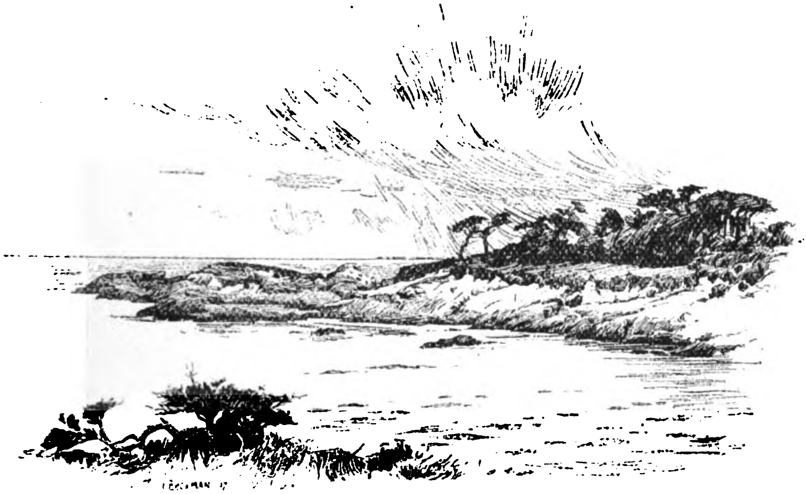

Fig. 4.—The Coast of the Pacific at Cypress Point, near Monterey.

this neighbourhood represent the vertebrates in a less interesting way. Mr Leverett M. Loomis, curator of the California Academy of Sciences, tells the writer that the coast line at Monterey is particularly prolific ornithologically; it includes among its common birds, cormorants, pelican, auklets, murres, and albatross. Among fishes there are several forms of especial interest. A species of *Chimaera* (*Hydrolagus colliei*) is plentiful in deeper water, twenty or more being a not unusual catch by a single boat. The hag-fish (*Bdellostoma stouti*) is one of the most common forms of the bay; and in some localities it is so abundant that it becomes a serious nuisance to the fishermen.

BASHFORD DEAN.

COLUMBIA UNIVERSITY, NEW YORK CITY,
April 1, 1897.

Gilbert van Ingen

THE SEVENTIETH BIRTHDAY OF CARL VON KUPFFER.

HIS LIFE AND WORKS.

BY

PROFESSOR BASHFORD DEAN.

Reprinted from SCIENCE, *N. S., Vol. XI., No. 271, Pages 364–369, March 9, 1900.*

[*Reprinted from* SCIENCE, *N. S.*, *Vol. XI.*, *No. 271*, *Pages 364–369*, *March 9, 1900.*]

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THE SEVENTIETH BIRTHDAY OF CARL VON KUPFFER.—HIS LIFE AND WORKS.

PROFESSOR VON KUPFFER has lately passed the mark of three score years and ten and has received the congratulations of his students of many lands. Some of these, following the good German custom, have prepared memoirs in his honor which appear in a memorial volume and were presented him as a birthday gift. Von Kupffer has been a most helpful friend to the Americans who have carried on their investigations in the Anatomical Institute in Munich during the past generation, and it seems but just that at this time an American journal should pay a tribute to his life and work.—EDITOR OF SCIENCE.

Carl von Kupffer ranks to-day as one who has taken a place within the innermost circle of comparative embryologists. He has long been recognized as a profound scholar in a broad field of zoological knowledge; he is best known, however, for his researches upon the structure, development and descent of the vertebrates.

In his biography von Kupffer presents an interesting parallel with the great embryologist, Karl Ernst von Baer. Both were natives of the Baltic provinces of Russia, students and graduates of the University of Dorpat, and sometime practicing physicians until drawn into zootomical-embryological research. Both were for a time professors at Königsberg, and showed a distinct bent towards the widely separate themes of Arctic exploration and craniology; they were equally interested in matters relating to fish and fishery and contributed important memoirs to this subject. On the other hand they had in general but little leaning towards work of the systematst. Both left Königsberg for wider fields, von Baer, however, to largely lay aside his embryological researches, the other to extend and correlate his.. An interesting difference between the two embryologists is this, that von Baer had completed his most important work when he was scarcely over forty years of age, while von Kupffer had not begun his best known work until he was over sixty. A further difference is that Kupffer has held fast to the early themes of his research. Von Baer lived until his eighty-sixth year; von Kupffer has entered his eighth decade with every prospect of many years of active work.

Von Kupffer has devoted forty-five years to his researches. And these he has embodied in upwards of fifty memoirs. The number seems relatively small—the bibliography of von Baer is six times as great—but this is explained by the fact that the papers are mainly of a critical character and are the fruit of intricate and time-consuming studies, just as von Baer's 'Entwicklungsgeschichte der Thiere' was the outcome of no less than nine years' of assiduous labor.

The writings of von Kupffer deal in the main with problems in special fields of embryology. A number of his well-known papers are contributions to histology, and there are several dealing with craniology, including the memoirs on the skull of his illustrious predecessor in Königsberg, Immanuel Kant.

The histological work of von Kupffer extends over a wide range of subjects. To cytologists he is known as a pioneer in the study of the ultimate nature of protoplasm. Thus, according to Bütschli, he ranks as the first to demonstrate satisfactorily the reticulo-vesicular character of protoplasm in living tissue. His observations in 1870 in the follicle cells of Ascidia showed distinctly the reticular meshwork and the breaking up of the cytoplasm into ultimate 'vesicles.' He also indicated for the first time (1870) the radial arrangement of the alveoli around the nucleus, together with the 'marginal alveolar layer.' The term 'paraplasm' used by von Kupffer in 1875, is still in use (as the equivalent of what at present is more often known as 'metaplasm') although in a somewhat different sense than that in which it was first used. His sustained interest in this theme was lately shown in his inaugural address (1896) as rector of the University of Munich.

The processes of the fertilization of the egg have been described by him in several forms. In an early paper on this subject he expressed his belief that in large meroblastic eggs a process of physiological polyspermy occurs, a view which his student, Professor Rückert, and other investigators have since confirmed and extended. His studies on fertilization have thus been important as leading the way for other papers from his laboratory—such for example as those on the fertilization of the lamprey and of the teleost by his devoted friend, Dr. A. A. Böhm, and also the earlier work of Theodor Boveri.

Von Kupffer's work should next be noted in connection with the structure of glands. In his studies on the histology of the liver he proved the presence of the secreting vacuoles in the gland cells and of the in tralobular fibrous sheath. He next discovered the remarkable Sternzellen (or 'Kupffer's cells') in the wall of the portal capillaries: these he showed were not nervous, as was at first believed, but highly modified endothelial cells, and later he demonstrated their function as phagocytes. His researches on the development of the mammalian kidney should here be mentioned: these he carried on by means of serial sections cut by free hand—this was long before the time when section cutting became general—and by this means he was able to demonstrate more satisfactorily than had hitherto been done the early separation of the mesonephric from the metanephric kidney, and he first showed the essential relations of the permanent kidney and its ureter to the mesonephric duct.

Another of his histological works deals with the structure of the stomach, in this in a measure preparing a way for the exhaustive comparative studies of his student, Professor Oppel. Other contributions relate to the development of the liver, spleen and pancreas (in *Ammocoetes*) and afford striking evidence that these organs are closely related genetically. Further papers discuss the characters of muscle cells, and the origin of blood in the valves in the dorsal vessel of the leech (*Rhynchobdella*). In his earlier work he was also attracted into the puzzling field of the electric organs in fishes (*Gymnotus*, *Mormyrus* and *Malapterurus*).

Another and perhaps the most important line of his histological work relates to the structure of nerves. He thus demonstrated that the axis cylinder was not a solid structure in the sense of the earlier investigators. This condition he showed was artifact: the 'cylinder' is rather to be looked upon as an axial canal containing in its fluid contents the delicate fibrils. In the matter of the central origin of nerve fibers his further observations have yielded a basis of the new neurone theory. The difficult question as to the exact mode of termination of nerve cells in an end-organ he also successfully answered in one of his earlier papers; in the salivary gland (*Blatta*) he was able to trace the final arborescence of the nerve filaments on the wall of the gland cell and he described the discoidal enlargement at the tip of each fibril.

Von Kupffer had never played the rôle of a pioneer in any extended field of embryological research. He has done the work—which has only too often the greater value—of extending, correcting and interpreting the results of earlier observers. Thus his famous work on the development of the Ascidian was in the path which had been opened by Kowalewsky, whose results, as von Kupffer himself notes, were then almost universally discredited. Von Kupffer soon came to support the new cause and he even outdid Kowalewsky himself in advocating the closer affinities of the ascidians and chordates. He thus showed in the ascidian the continuity of the cord and brain, the 'segmentation' of the tail, the presence of 'spinal nerves,' and the distinctly chordate character of the notochord, together, later, with interesting homologies in the sense organs. And so too in his extended paper on the development of the Lamprey he took up the unfinished work, and succeeded in reconciling several discrepancies in the results of Max. Schultze and Shipley. But it should be understood that the results of pioneer investigators were to von Kupffer but as the foundation stones of detailed and original work. Thus in his paper on the lamprey he soon laid aside his purely critical studies and attacked a series of difficult problems relating to the origin of the mouth, the cranial nerves, and of the primitive conditions of the central nervous system.

Gastrulation is one of the most difficult processes with which the student of the development of vertebrates has to deal. And it is upon this theme that the work of von Kupffer has thrown no little light. It was formerly thought—and this was the rock which wrecked the results of Pander, Baer, and Rathke—that in the large yolk-filled eggs of such animals as reptiles and birds the germ-layers of the embryo arise one from the other by a process of splitting (delamination). Von Kupffer, however, was able to demonstrate that in these forms a process of infolding occurs, modified, it is true, but proving that the gastrulation of the higher forms is clearly homologous with that of the amphibia and many fishes. He was also the first to give a satisfactory interpretation to a characteristic structure of the gastrulation of the meroblastic types, the primitive streak. An especially remarkable feature of von Kupffer's work was that he made his interpretation of the invaginate character of the early gastrula of a meroblastic type in his study of the teleost—a form in which the appearance of the infolding process is so difficult to observe that his early results were for thirty years discredited—and it is only recently that the 'prostoma' in these forms is again described (Sumner). It was his earliest paper on teleostean development, by the way (Ref. No. 6; II.), which describes 'Kupffer's vesicle,' which in the matters of its homology and function has since been an unusually fruitful theme for controversy. We may note in passing that von Kupffer believed that the region of the prostoma was (as he also interpreted the primitive streak of amniotes) the *only* region of gastrulation in the bony-fish, that he failed to determine the invaginate character of the germ ring, and that he interpreted the early embryo as equivalent to the primitive streak, and not therefore to the actual embryo.

In connection with Kupffer's work on the development of the teleosts it should be mentioned that it is he who deserves the credit for the view that the cells of the blastoderm are the progenitors of the periblast nuclei, and that they also give rise to the tissue cells of the embryo, questions of great theoretical importance. His work on the development of the herring, undertaken in the interest of the Commission for the Investigation of the Fisheries of the German Ocean, is a further memorable contribution to the biology of fishes. Here for the first time in any extended embryological memoir photo-micrographs were introduced as plates.

Only a tithe of von Kupffer's publications relate to the development of mammals. His most noteworthy paper deals with the question of the 'inversion of the germ layers' which had been described in a rodents, a condition which appeared to be an extraordinary contradiction to the usual mode of origin of the germ layers. By means of a series of stages of the field-mouse he showed conclusively, however, that this 'inversion' was only apparent: during early growth the embryonic area bowed downward to the ventral side of the ovum, so that the flattened gut came to be apposed to the surface while the central nervous system was left to develop within the cavity of the ovum.

The philosophy of the vertebrate head has furnished the fruitful theme of von Kupffer's studies during the past ten years. And his memoirs (three of the series have thus far appeared) upon this subject are, I think, regarded generally as his *magnum opus*. His endeavor in these memoirs is to demonstrate by ontogenetic conditions in the lowest craniotes the mode of origin, phylogenetic, of the structures of the vertebrate head—brain, cranial nerves, sense organs, mouth region, muscles and skeleton. The plan of this series accordingly recalls somewhat that of Dohrn in his 'Urgeschichte der Wirbeltiere,' although the views of their authors are usually widely at variance. Von Kupffer derives the ground plan of the conditions of the vertebrate head from that in the protochordates while Dohrn, for a long time, at least, has been the strong supporter of the famous annelid theory. Certain it is that the results of von Kupffer are welcomed by the warmest interest even by those whose faith in the great value of developmental characters as tests of phylogeny has been severely shaken. And all will admit he has already been able to clear up a number of doubtful points in cranial problems: thus, to mention but an instance or two of the general value of his work, it is now found possible to determine definitely the most anterior point of the brain and to compare with certainty—thanks to his revision of topography—such widely distinct and important regions as those of the lobus olfactorius impar, the recessus opticus and the tuberculum posterius, in all chordates from amphioxus to man. So, too, his determination of the metameral characters and subdivisions of the cranial nerves bids fair to become a classic if not an epoch-making contribution to the philosophical side of this long investgated and difficult subject.

In a late number of the Münchener Medicinische Wochenschrift, Professor Rückert* pays a tribute to von Kupffer's remarkable power of continuing and improving the quality of his work in spite of the burden of seventy years, and he concludes his paper with the wish that von Kupffer will long be spared to continue his good work. In this wish his American colleagues heartily join. BASHFORD DEAN.

The following bibliography of von Kupffer is largely due to the kindness of my friend, Dr. L. Neumeyer, of the Anatomical Institute in Munich.

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W. D. Matthew

THE CARNEGIE INSTITUTION.

BY

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[*Reprinted from* SCIENCE, *N. S., Vol. XVI., No. 408, Pages 641–644, October 24, 1902.*]

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THE CARNEGIE INSTITUTION.

ONE of the cardinal difficulties which must, I take it, be met speedily by the administrators of the Carnegie Fund (and the present discussion may aid in showing what some of the difficulties are) is the problem how to divide its benefits fairly. For, according to the deed of the benefactor, the purpose of the gift is evidently to stimulate science in its widest acceptation, in all of its branches, applied, no less than theoretical. And to expend its goodly income on lines which will be in fullest keeping with the trust is by no means an easy task. Its trustees are bound to distribute its benefits fairly, but they may well be puzzled by the number and kinds of questions which require a practical answer. They have thus immediate opportunities for investment, which are legitimate, attractive, and which may never befall them again—*e. g.,* the acquisition of the Woods Hole station. They have also to deal with the importunate and well-deserving (colleges, societies, experimental stations, journals and individuals), some of whom, I fancy, are aggrieved at not having already received an annual sop from the Carnegie funds.

As a matter of fact, however, the Institution, in spite of its ten millions of dollars, is yet too poor to yield the immediate and miraculous draught of scientific results which many of us expected. For science in these days has so many branches that the Carnegie funds will be able to increase —as far as funds can—the yearly scientific activity, as Professor Cattell estimates, by only about one per cent. There are, roughly speaking, about thirty main departments of scientific work, and computing the income of the Institution at $300,000, the share of each department could hardly equal $10,000 a year. Moreover there is the important question of expense of administration to be considered. Some have even suggested that a central organization be amply housed, and at considerable expense. But I for one fail to see that such an outlay would be for the greatest good of the scientific community. It would be rather a delectable than an all-important thing to have a well-built and splendidly equipped Carnegie headquarters in Washington, with a corps of high-salaried officials to give public lectures and to supervise select laboratories—at an expense of at least half the income of the institution. The main benefit in such a plan would, it seems to me, be too nearly local and individual to prove in best accord with the highest purposes of benefiting science. On the one hand the officials, chosen for eminence *after* they have done their major work, would, before many years, become quasi-pensioners, and unless they were removed ruthlessly, say by an age limit, they would soon cause the Institution to lose touch with recent developments and recent needs in science. And on another hand the Institution is not wealthy enough to run any risk of acquiring a political environment, or of evolving a highly specialized bureaucracy. And this risk is the less needful since the average investigator is apt to work for the benefit of the cause, unaffected by the stimulant possibility of some day being promoted to Washington with a salary of $10,000, to sit in a conspicuous chair, and perhaps as time goes on to have a gold-braided coat, frogged with gold acorns. Contrariwise, I feel strongly that the great purpose of the Institution would be best served if there were as little salaried officialdom as possible for the actual administration of its affairs. And I fancy that very few of the eminent scientists who are invited to become members of the committee, will refuse to act, and to act zealously and effectively, because they are not paid.

The fair-division problem of the trustees, then, narrows itself down to this: What branches of science are to be looked upon as equivalent candidates for benefits? And which ones are to be favored to the detriment of others? And for what reasons? Looking over a classified list of the 'sciences' one can readily select thirty branches, each of which, like electrical physics, or morphology, or organic chemistry, or psychology, or paleontology, would make the best of use of a Carnegie dividend. And a trustee would probably be embarrassed to have to pare down one of these branches for the benefit of the others. There is something to be said in favor of establishing a pro rata scheme of appropriations for the branches in accordance with a census of the number of worthy investigators which each branch includes. But, on the other hand, there are weighty reasons why such a plan would be inexpedient, since the number of workers may be out of proportion to the importance of their results, tested from the scientific standpoint. But here again is the difficulty of setting up an accurate standard of comparison. In any event there could be made a satisfactory division of science into approximately equivalent branches, say to the number of twenty-five or thirty, and for each of these an honorary committee be chosen. And the Institution, by the testimony of such expert committees, could be reasonably sure that its annual appropriations would find their way where they would do a maximum of good. And each sub-committee could, it seems to me, best decide what share of its grant should be used for publication, individual grants, exploration, prizes for special themes of research, etc. So, too, to what degree a new or retarded division of its activities should be fostered to the detriment of an older and better equipped one.

In the matter of the character of work which it should be the general policy of the Institution, *i. e.*, in every branch, to provide for, I would suggest as most important: (1) publishing, (2) facilitating bibliographical work, (3) procuring material for research, (4) granting funds or fellowships. And the list could be readily increased.

1. *Publishing.*—One estimates conservatively, I believe, in affirming that *there are to-day enough worthy researches of American investigators to warrant the expenditure of the entire income of the Carnegie funds for purposes of suitable publication.* It has recently been suggested that American publications would be greatly aided by the establishing of a Carnegie bureau of engraving and printing which should execute at favorable rates the work of

various societies. Such well-intended means, however, would bring with them certain practical drawbacks, and, judging from precedents, one would not be surprised if the output of the establishment became more costly and less efficient than that of skilfully directed private enterprise. More useful in practice, I fancy, would be direct grants for publication, say to periodicals of the stamp of the *American Journal of Morphology,* and permission of Congress for lithographic work to be brought through the customs free of duty when sanctioned by the Institution. The longer, more important, elaborately illustrated and carefully selected memoirs might appropriately be brought out by the Institution, and a splendid series of quarto and folio volumes would be a fitting fruit of our national work, to be to us in time what the *Philosophical Transactions* are to the British. And such publication I place among the very foremost needs of American science. We need hardly recall that for publication of zoological memoirs, to take an example, American authors have had either to accept the charity of foreign journals or to allow their researches to remain unprinted.

2. *Bibliography.*—All workers in science need skilful and energetic help in the thankless drudgery of reference hunting. To give them necessary aid the Institution should at once subsidize the Concilium Bibliographicum, an American enterprise, supported largely by the charity of Switzerland. The Concilium lacks only funds to enable it to extend its excellent work into various departments of biological science. Its work in zoology is invaluable. In con-

nection with such a bureau it may be possible for the Institution to publish a series of bibliographical volumes (on the lines of the recent paleontological work of Dr. Hay) which will be a permanent boon to students in all branches of science. Another bibliographical development, in connection possibly with the Concilium, is a bureau to provide applicants with necessary literature lists; also a bureau in correspondence with libraries to place in the hands of investigators works of reference which cannot be procured by local means.

3. *Research Material.*—In some lines of research this can be secured only with considerable outlay. Thus for an important embryological study a sum of from five hundred to ten thousand dollars is not an uncommon expenditure. In this country such expense has usually been borne by generous outsiders or by investigators themselves; in rare cases universities or societies have contributed. In Europe, however, societies have usually furnished appropriations, and in America, other calls permitting, the Carnegie Institution might justly follow their example. On the other hand, the maintenance of laboratories appears to me of less immediate value in encouraging research, for there now exist many and well-equipped laboratories in connection with university work throughout the country, open, too, on generous terms to any qualified investigator. The question of the Woods Hole station is, I think, exceptional, since nowhere else in the United States can marine investigations in all fields be carried on to similar advantage. Special experimental stations, however, for statistical and other variational

studies are not as immediate a need since most of their work can be carried on in connection with the agricultural schools of many states. In this regard the history of foreign universities teaches us that research will flourish in spite of the lack of modern and splendidly equipped buildings. Men and books are at present less prevalent in our country than are tolerable quarters in which to house them. In no event would a Carnegie laboratory, I believe, be warranted in supporting classes for instruction as long as worthy investigators are in need of books, research material and means of publication.

4. *Grants and Fellowships.*—When the foregoing needs are suitably provided for the creation of fellowships would give very desirable means of stimulating activity in research. And in this matter one endorses heartily the suggestion of Professor Cattell in his recent paper in SCIENCE. None the less it is still a question whether, money being limited, more productive results would not follow the system employed by various trust funds of granting definite sums to deserving investigators to enable them to complete definite pieces of work.

COLUMBIA UNIVERSITY. BASHFORD DEAN.

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[*Reprinted from* SCIENCE, *N. S., Vol. XVII., No. 428, Page 433, March 13, 1903.*]

THE EGGS OF THE EASTERN ATLANTIC HAG-FISH, MYXINE LIMOSA *Gir.*

EGGS of a hag-fish from the Newfoundland banks were described by the present writer in 1900 (*Mem. N. Y. Acad. Sci.,* Vol. II., pp. 31–43) from specimens in the Verrill collection, Yale University. They were then looked upon as belonging to the common North Atlantic *Myxine glutinosa* Linn. Since that time, however, the eggs of five other species of myxinoids have been examined, and a fairly definite knowledge is at hand in the matter of the degree of variation in these eggs within specific limits. It follows from these studies that the differences between the eggs of *M. glutinosa* as described by Jensen and those of the Newfoundland form are too great (*op. cit.,* pp. 35, 42) to warrant the eggs of both types to be included under *Myxine glutinosa.* Accordingly I have come to the conclusion that we must consider the American specimens as probably representing *Myxine limosa* Girard, the common hag-fish of Maine. I would also note that a study of variation among myxinoids has recently led me to conclude with Mr. Garman that *Myxine limosa* is to be accepted, not as a variety of *M. glutinosa,* but as a valid species.

BASHFORD DEAN.

[*Reprinted from* SCIENCE, *N. S., Vol. XIX., No. 471, Pages 64–65, January 8, 1904.*]

The Lower Devonian Fishes of Gemünden. By R. H. TRAQUAIR. Transactions of the Royal Society of Edinburgh, Vol. XL., Pt. 4, pp. 723–739, pls. 7, 1903.

Dr. Traquair's recent paper will be welcomed as throwing light on *Drepanaspis,* one of the lowliest vertebrates. In earlier papers Dr. Traquair has briefly referred to this armored form, known only from the lower Devonian slates of Rhenish Gemünden: in the present memoir he completes his studies upon it, basing them upon a remarkable series of the fossil which he has collected during the past dozen years.

Gemünden fossils, one may note incidentally, are remarkable for the great beauty with which their external characters have been preserved, shown especially in mollusks, trilobites and starfish; and the armored fishes have proven no exceptions to the rule. The specimens however, are always pyritized and are therefore, unfortunately, valueless for histological study. Besides *Drepanaspis,* the only armored fish known hitherto in detail from this horizon, Traquair now describes a *Coccosteus,* a *Phlyctænaspis* and two forms *incertæ sedis.* Of these the first, *Gemündina,* is a fish somewhat ray-like in form, characterized by a stout vertebral column and an integument well encrusted with shagreen denticles. What it is no one can say, although its describer regards it as 'possibly a chimæroid,' admitting, however, that his idea 'rests more upon feeling than upon anything else.' Until, therefore, more and better material can be secured one is constrained to conclude that nothing further need be said about its affinities. *Hunsrückia,* the second problematical form, is represented only by a series of vertebral arches whose structures suggest very doubtfully a pleuracanth shark. Regarding *Drepanaspis* the paper gives many interesting details, and they do not, we find, lead the author to alter his earlier opinion as to the affinities of this form. He places it near the classic *Pteraspis,* and regards it as the more generalized, a view which will probably meet general acceptance. It is a source of satisfaction to students of these earliest chordates that in the present form both dorsal and ventral sides are now known with fair accuracy. Desirable, none the less, is a better knowledge of the region of the mouth, which is practically terminal, surrounded by a rather indefinite series of dermal plates, and of the lateral angles of the body, where possibly an opercular opening is situated. And while we are duly grateful to Dr. Traquair for his skilful and continued efforts to elucidate this remarkable form, we are none the less impatient for further details. The object is, at the best, difficult to orient, and as a symptom of this it may be doubted whether the interpretations of even an author of Dr. Traquair's experience and acumen are always valid. Thus, his grounds seem inadequate for distinguishing dorsal and ventral sides. In no specimen figured is the relation of the dorsal lobe of the tail shown convincingly to be continuous with the so-called dorsal aspect; moreover, the eyes occur on the side which Traquair regards as ventral. Unless additional evidence is forthcoming, it would accordingly seem to me more probable that the 'labial' of Traquair was the 'rostral' plate, a structure which appears constant in *Heterostracans.* This interpretation would permit the eyes to be seen at the sides of the dorsal armoring, as indeed, they occur in *Pteraspis,* and would enable us, at the same time, to locate the greater number of the larger plates on the dorsal side. This conclusion is the more satisfactory on comparative grounds, since there is not an instance in the chordate phylum in which the eyes and the most complete part of the armoring appear on the (morphological) ventral side. And I doubt whether, on the present evidence, we can assume, with Professor Patten, that *Drepanaspis* might have evaded the law of vertebrate orientation by swimming on its back. Dr. Traquair has attempted to solve this dorsoventral difficulty by suggesting that either the orbits are 'sensory' pits, *i. e.,* not orbits, or that, 'since the specimens are all crushed absolutely flat, it is by no means certain that in the original uncompressed condition the openings did not look out to the side.'

BASHFORD DEAN.

[*Reprinted from* SCIENCE, *N. S., Vol. XXIII., No. 600, Pages 986–987, June 29, 1906.*]

TWO LETTERS OF DR. DARWIN: THE EARLY DATE OF HIS EVOLUTIONAL WRITINGS.

SEVERAL letters of Erasmus Darwin have lately come into my possession, and two of them seem worthy of publication, if only for the reason that reference to his evolutional ideas seldom occur in his correspondence. In this regard, for example, Charles Darwin states in his introduction to Dr. Krause's 'Erasmus Darwin,' that 'most of the letters [of his grandfather] which he possessed or had seen, are uninteresting and not worth publication.'

The earlier letter, I may note, has the merit of referring to Dr. Darwin's work on the anatomy of plants, and to his ingenious effort to show closer correspondence between the organs of the higher plants and the higher animals. Indeed, as we know from other sources, he even expected ultimately to find in plants the homologues of the animal nerves, ganglia and sense organs. Accordingly, we are not surprised to find that he refers here, in quite a matter of fact way, to the 'blood' and the 'two systems' of a plant. And he gives us also a glimpse of laboratory methods, and of his interest in getting in prompt touch with the results of foreign workers.

The first of these letters is addressed to 'Sir Joseph Banks, Bar$^{t.}$ Soho Square London.' and is as follows:

RADBURN MAR. 16—82

Dear Sir,

I return'd your sixth volum of the Amœnit. academ. & thank you for the loan of it. I should have sooner sent it, but hoped to have received another copy of Murray, & also that Dr. Linneus's supplementum would have been procured from abroad, & thence meant to have returned them together.

Mrs. Blacburn favor'd us with a copy of Murray, but desired it to be returned in three months, which it was to a day; & as I could procure but one other, & our society was not all resident at Lichfield, we were distressed on this account, but are still flatter'd with daily hopes of more copies being imported. I am sorry you say the remainder of the supplementum is not likely soon to be had.

On looking over Malpighi, & Grew, & Hales, the physiology of plants appear'd to me, not to have hitherto been under the attention of any one perfectly acquainted with the animal economy. Last summer I contrived to inject the absorbent system of the Picris with a colour'd liquor; & as the blood of that plant is white, these two systems were beautifully apparent to the eye. On reading a manuscript translation of Mr. ——— a Sweedish naturalist, I found the authors, I mentioned to you in my last, had made a set of similar experiments; & I had designed to have investigated this subject, so little understood at present, farther during the summer.

This however I have now laid aside, for perhaps more important, tho' less ingenious occupations; & shall therefore decline giving you the trouble of sending me the books you are so kind as to offer, both in your last, & in a former letter of yours, I am S^{r}.

with great respect
your obed^{t}. servt^{t}.
E. Darwin.

The second letter is of livelier interest. He denies having 'stolen' his 'Botanic Garden,' or of even having heard of its prototype, probably the 'Universal Beauty' of Brooke (1735). And he modestly predicts of the effect of his evolutional 'conjectures.' Finally, he refers to the 'Zoonomia,' as having been on his work table—or rather 'lain by him' for 'nearly twenty years'—*i. e.*, since about 1771. That the work here referred to is the 'Zoonomia,' there can be no doubt; he obviously means an extended evolutional work, and, in a letter to a son, dated the following year (cited in the introduction to 'Erasmus Darwin,' above referred to, page 102), he says, that "he is studying his 'Zoonomia.'" It is, of course, well known that this work was long intended for posthumous publication. But the exact time when the first draft of this pioneer evolutional treatise was completed is not known. Charles Darwin says, in the Introduction, that it was intended for posthumous publication as early as 1775; and, according to the remark in the present letter, it may have been fairly complete several years earlier. There is no evidence, however, that it antedated the evolutional writings of Buffon (1765).

This second of these letters is addressed to 'Dr. Percival Physician Manchester,' and reads as follows:

Dear Sir,

I am much obliged to you for the kindness of your letter; & thank you for your inquiry into the merits of a poem, from which the Botanic Garden was supposed to have been stolen; an accusation which however I had not heard of, & am the more indebted to you for shewing the falsity of it.

The first part, which you are so obliging as to inquire after, is nearly printed; & I suppose will be out, if not delay'd by the engraver, in 3 or 4 weeks. It is longer than the other, & if you are at the trouble to read it, I shall be glad of any remarks, which may improve a second edition of it; if such should be called for.

I hope you will be amused, tho' not convinced, by the conjectures in the notes on coal ("upon geology," stricken out), on the winds of this climate, & on the use of the honey to the vegetable economy.

Was I sure of such candid readers, as yourself, I should be tempted to print another work, which has lain by me nearly 20 years. Adieu.

I am, dear S^{r}.
Your much obliged
& obed^{t}. serv^{t}.
E. Darwin.

Derby
Jun. 18—91.

Bashford Dean.

Columbia University.

With the Compliments
of Bashford Dean.

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REPRINTED FROM

THE QUARTERLY JOURNAL OF MICROSCOPICAL SCIENCE.

The Early Development of Amia.

By

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With Plates 30—32.

GANOIDS, or more accurately Crossopterygians and Chondrostean Actinopterygians, must be looked upon as, in many ways, a transitional and intermediate group. For, on the one hand, the evidence is becoming conclusive that the Teleosts are to be regarded as its highly differentiated descendants; and, on the other hand, its most primitive members have certainly the closest ties of kinship with both the early sharks and lungfishes.[1]

Amia calva is doubtless, at the present day, the sole survivor of the race of Mesozoic Ganoids of which Caturus or Megalurus may be taken as a type. It claims, therefore, an especial interest as most nearly the ancestral form of some, if not all, of the recent Teleosts; for its structures are peculiarly Teleostean, and its closely kindred forms occurring from the Oolite to the Cretaceous provide the actual stepping-stones to the Clupeoids.

But in embryology the Ganoid and the Teleost still stand widely separate, and there has even been a tendency to look upon these kindred forms as representing distinct phyla, early divergent from a primitive chordate ancestor. And it is therefore evident that, before Teleosts can be conclusively shown to be of Ganoidean descent, it becomes necessary to demonstrate that well-marked transitional characters exist not only in their structures, but in their ontogeny.

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[1] The writer refers to the structural nearnesses of the early Crossopterygians (e.g. Gyroptychiids), Phaneropleurid Dipnoans, and Pleuracanth sharks. He also notes that decidedly shark-like features are now found to be present in the early development of the sturgeon, and especially of the gar-pike.

It has accordingly been my object in the study of Amia to determine its developmental relationships. For in the ontogeny of this most Teleostean Ganoid there seemed evidently the key to the solution of the entire problem—on the embryological side—of Teleostean descent; and, conversely, the degree of its developmental unlikenesses to the types of sturgeon and gar-pike could not fail to prove suggestive.

Embryonic material of Amia was to be obtained at Pewaukee, Wisconsin, a locality which has long been known as an exceptionally favorable spawning ground. It was here that Allis, Ayers, Strong, Ecclesheimer, and Fülleborn had succeeded in securing developmental material, and this locality appeared, therefore, far more reliable than Black Lake, St. Lawrence County, New York, where, from my preceding studies on Lepidosteus, I was but moderately sure of success. In order to undertake the collecting trip, I was enabled through the kindness of President Low, of Columbia College, to leave my duties as early as May 14th of the present year. Proceeding directly to Wisconsin, I was fortunate enough to secure eggs and larvæ by May 17th, and on May 19th had the opportunity of observing the spawning fish and to secure the earliest cleavage stages. Cold and rainy weather then proved favorable to my studies, for it retarded the development of the eggs, and gave me an opportunity to observe the living material, and to prepare the figures of those stages especially which in surface view (as my studies of Acipenser and Lepidosteus[1] had taught) could not well be examined in the fixed material.

By the time of my visit, however, the spawning season had

[1] 1895, DEAN, "On the Early Development of Gar-pike and Sturgeon," 'Journal of Morphology,' vol. xi, No. 1.

practically ended. Indeed, so late was the time of my arrival at the spawning ground that it was altogether due to the kindness and skilful efforts of Mr. Henry Meyer of Oconomowoc, that my trip proved successful. I found it impossible, accordingly, to secure at the same time both male and female fish in spawn for purposes of artificial fertilisation, and I was unable to employ the method of caring for the eggs which had proved so helpful in the studies of Acipenser and gar-pike. Fortunately the eggs of Amia were found to be especially hardy; they might be removed from the nests and retained in floating hatching cases, often even kept in the laboratory in pans and trays without serious losses. From their adhesive membrane, however, I have no doubt that the same method of procedure would have succeeded as in the case of the other Ganoids. In fixing the eggs, alcoholic (50 per cent.) picro-sulphuric mixture was generally used.

As to the general habits of Amia, but little need be said in the present paper; the notes of Dr. Fülleborn[1] regarding them have been fully confirmed. The fish is especially abundant in the Wisconsin lakes, and as it is worthless as food, and persists in taking any and all baits, it is not looked upon kindly by the local fishermen—especially as it not infrequently breaks both his rod and line. Luckily for him, perhaps, it feeds mainly during the evening and night,—but even then he meets it continually when using the jack-light. The strength and apparent clumsiness of the fish are to be emphasised; when disturbed in the shallows it will break through the water noisily in its strong efforts to escape.

The themes of the present paper have been arranged as follows:

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[1] 1895, Fülleborn, "Berichte über eine zur Untersuchung der Entwickelung von Amia, Lepidosteus, und Necturus unternommende Reise nach Nord-America," 'Sitzungsberichte der Akademie der Wissenschaften zu Berlin,' Bd. xl, ss. 1057—1070.

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I. The Breeding Habits of Amia.

The account of the spawning habits of Amia, as recently given by Fülleborn (op. cit.), has been entirely confirmed by the present writer. A number of additional notes[1] are presented in the following pages.

In the beginning of the spring Amia makes its way from the deeper water, where it has remained sluggish during the winter season, to the shallows in the vicinity of its spawning ground. This is usually in the swampy end of a lake, where the water is well filled with reeds, stumps, Chara, Potamogeton rootlets, here and there broken by little clear channels or inlets several feet in depth. In this neighbourhood the fishes are early seen, often in numbers, sunning themselves near the surface. They are at this period active, and may not be closely approached. Like the gar-pike, they are then usually in companies, the fish well separated.

The spawning season is an early and somewhat extended one, and is apparently induced by the first warm days of spring. The time of spawning in 1894, as recorded by Fülleborn, extended from the beginning of May to the first days of June. In the spring of 1895, however, although the previous winter had been unusually severe, a few warm days in April appear to have been the cause of earlier spawning. As with the gar-pike the spawning then appeared, and has been almost simultaneous,—a general "run," after which the season was concluded by an intermittent spawning, with a nest here and there. At the height of a "run" as many as a half-dozen nests, as fishermen stated, were found to occur within the space of a few square yards. The fish were observed depositing their eggs as early as April 25th, and before the 1st of May the spawning appeared to have been generally completed. By the middle of this month larvæ were abundant, and from their uniform size in the different localities, and in different lakes, the spawning time could have been varied but little throughout the entire region.[1]

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[1] These include observations made by the present writer at Pewaukee, Black Lake, and in the South Carolina rivers.

Immediately before spawning it is said that the fish divide themselves into parties, each comprising a female and several males, and that they then circle about nearer and nearer the shallows. A spawning place is selected—a well-sheltered spot with a water depth of about a foot—and a nest is there prepared. And it seems evident that nests are prepared sometimes well in advance of spawning, for several were noted by the writer which were occupied by the fish for a number of days before the eggs were deposited. The mode of building a nest is in some ways doubtful: fishermen state that the spawning party prepares it by constant circlings before the time of spawning, and this view seems entirely corroborated by a careful examination of the newly made nest; the soft weeds and rootlets appear bent and brushed aside in a way that gives it somewhat the appearance of a crudely finished bird's-nest.

The mode of depositing the eggs appears to be entirely similar to that described by the present writer in the case of the gar-pike. The spawning fish leave the nest from time to time, returning in company. The eggs and milt are emitted simultaneously. The fishes apparently rub closely together, since scales are found scattered in the nest bottoms, as noted by Fülleborn, and now confirmed by the present writer. The eggs become instantly adhesive, sticking to any portion of the weedy nest which at the moment they happen to touch (e. g. Potamogeton or bulrush rootlets, Fig. 1). The writer has seen a nest in which—judging from the wide difference in the cleavage stages—the oviposition must have taken place during a period of about twelve hours. Another nest, on a somewhat warmer day, appeared to have been filled with eggs within about half an hour, since all cell stages were notably uniform. The number of eggs the writer roughly estimates as in the neighbourhood of a million.

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[1] The present writer finds the spawning region very general: nests were found in La Belle Lake (cf. Fülleborn, op. cit., p. 1059).

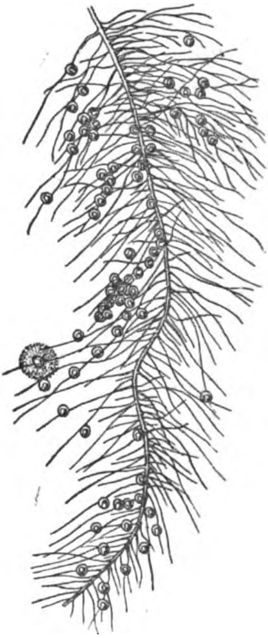

FIG. 1.—Eggs of Amia. Shown as collected, attached to root of bulrush. × about $\frac{7}{8}$.

Shortly after oviposition a single male takes his position on the nest—whether by driving the others away or not the writer has been unable to determine. Here he remains until the eggs are hatched, sometimes in the nest, circling slowly about, sometimes in the adjoining "runway," as in Fig. 2, his head and pectorals projecting over the nest. It is evident that his constant breathing is an important source of the eggs' aëration: his movements, moreover, aid, no doubt, in sweeping the nest free of sediment, from which, on account of their position, the eggs might otherwise suffer.[1]

Shortly after the eggs are hatched the entire swarm of larvæ leaves the nest. A fine nest of eggs, from which the writer had expected to get the young just before the time of their hatching, was found to be entirely deserted at a time when the young could not have been older than twenty-four hours. The closest search in and about the nest revealed no trace of their whereabouts, although from their larval habits it was thought that they should surely be found attached to the neighbouring weeds or deep in the mass of root-fibres and detritus of the nest bottom. They had evidently left the nest in a body, and were

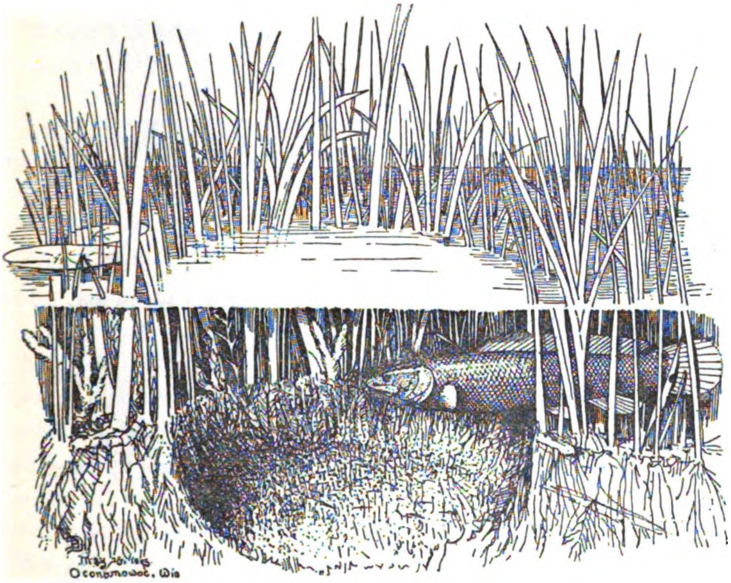

Fig. 2.—Nest of Amia.

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[1] The few remaining eggs of nests which had been "robbed," and to which the male did not return, were found to become destroyed by fungus.

nowhere in the immediate neighbourhood. It was plausibly suggested by Mr. G. W. Kosmak, who then accompanied the writer, that they had been taken away by the male fish, attached to him by their sucking dishes.

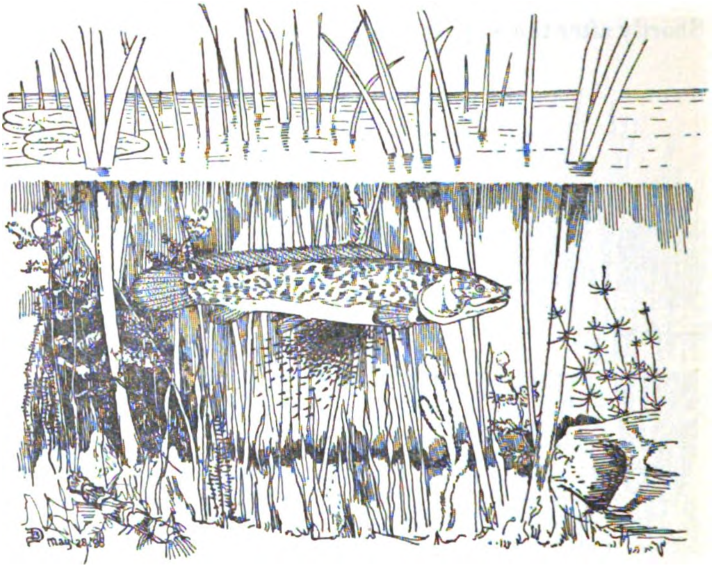

FIG. 3.—Young of Amia attended by male.

It is certain that when the male reappears it is with a swarm of nestlings; but they are now well grown ($\frac{5}{8}$—$1\frac{1}{4}$ inches). With these he remains for a time in the neighbourhood of the spawning ground; then he appears to gather them together with constant circlings and slowly takes his way to the neighbouring shallows (Fig. 3). The fish is courageous in the protection of his charges, remaining with them, facing the danger, until the boat approaches within a couple of yards; in one instance the writer has seen the fish actually pushed aside with the handle of the spear.

II. The Early Development of Amia.

A. The Egg and Egg Membranes.—The egg, shortly after its deposition (15″—30′), presents the general appearance of Pl. 30, fig. 1. It has assumed an oblong form, averaging 2·2 × 2·8 mm. The germinal area, even in freshly deposited eggs, was well defined as a whitish cap reaching down to about one third of the egg's longer or vertical axis. Its yolk pole region is pale greyish in colour (resembling that of the freshly laid sturgeon egg), and retains this colour throughout earlier development, appearing dingier and browner, however, as the outer membranes become soiled.

A single micropyle probably occurs, as in Lepidosteus and the Teleosts. Of this, however, the writer is by no means sure, as his only observation was made hastily during a collecting trip, and he neglected to immediately harden his material.

The egg membranes are essentially similar to those of Lepidosteus and Acipenser; they appear, however, relatively thinner and more intimately associated with the egg. They are not to be removed by needles until the embryo has become well established; even then the process is a difficult one. There is present a well-marked zona radiata and villous layer; these, in the younger stages, are approximately of equal thickness. The radiata is more compact in structure than in the other Ganoids; the villous layer, on the other hand, is of a far looser texture, its elements crumpled and intertwined, the heads of the villi oblong and swollen. At the point of the egg's attachment, e. g. the stem of waterweed, furthermore, as may be seen in the adjoining figure (Fig. 4), the villi become enormously elongated, their heads firmly fixed to the attaching object. A granulosa occurs irregularly; it sometimes appears as a cell tract of considerable size, at other times it is almost wanting; it has certainly no such important relation as in Acipenser. In Pl. 30, fig. 1, the egg is shown attached to the waterweed; its membranes show a broad jelly-like base consisting of the elongated villi, and the mottling roughnesses of the egg surface represent patches of the granulosa.

The germinal area, as above noted, is readily to be determined by the unaided eye, even at a very short time after the egg is deposited; its margins fade gradually into the yolk somewhat above the equatorial region of the egg. Its marked appearance is doubtless the reason of the oblong form which the egg early assumes. This shape, moreover, would seem to bear with it a specialised developmental character in that it does not, in the event of the egg's displacement, permit the germinal region to rotate backward into its vertical position, as it so readily does in the case of the sturgeon and gar-pike. The writer has found, however, in the early stages of segmentation that the cleavage planes occur in the normal way when the position of the egg was reversed. In these instances there was a slight attempt at the rotation of the germ disc, but in no case was this complete as far as the present observations went. The power of rotation in the eggs of Amia, it might here be noted, becomes more perfect at the subsequent stages of development; towards the close of gastrulation the egg's outline becomes more

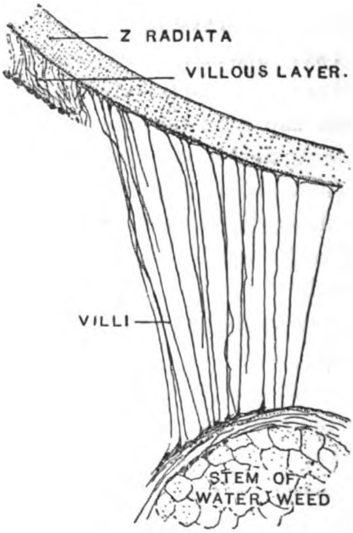

Fig. 4.—Egg membranes of Amia. × about 180.

nearly spherical, and the writer has observed that the blastopore of inverted eggs could slowly rotate downward.

Deutoplasm and germ region are more early to be distinguished in Amia than in other Ganoids. Studied in vertical sections (Pl.31, fig. 21) the line of union of yolk and germ may be traced in the plane passing through the lower rim of the germ area; this plane of demarcation, however, on closer examination, proves to be broader than it at first appears; the yolk spherules may be traced, becoming smaller and smaller, well into the germ area. The nucleus, small in size, takes its position in the lower portion of the germ.

"Pigment" is practically absent in the late as well as in the earlier stages; in this regard the eggs of Amia and the garpike closely correspond.

B. **The Rate of Development.**—The following summary of the rate of development relates to a particular set of embryos. It is evident, however, that the time-proportion between the different stages is relatively uniform for a longer or shorter period of development. The position with regard to the upper and lower egg poles assumed by the growing embryos was observed by the writer to correspond with those he has already recorded in the Lepidosteus. Disturbance in the actual position of the egg, notably during the stages earlier than gastrulation, is attended with variations of position; the lack of the power to rotate backward into its normal position has already been recorded, p. 10.

Hours after oviposition.	Hours.	Hours after oviposition.	Hours.
First cleavage	1	Early gastrula	47
Second cleavage	2	Blastopore closes	80
Third cleavage	3	Embryo's length 90°	68
Fourth cleavage	4¼	,, ,, 180°	80
Fifth cleavage	5½	,, ,, 270°	124
Sixth cleavage	6⅞	,, ,, 320°	158
Seventh cleavage	7⅛	Egg hatches	192

The rate of hatching, as recorded by Fülleborn, varied between eight to fourteen days. The present writer finds, however, that the eggs hatched far more rapidly than this during the latter part of the present season,—in one case (May 24) within four days, in all cases not longer than eight. A sudden increase in the water temperature, as in the Lepidosteus, and, for that matter, doubtless as in all other fishes, hastens the rate of development.

C. Segmentation.—The segmentation stages of Amia are readily studied in the living egg, the transparency of its membranes permitting the cleavages to be followed. They are, however, far more obscure than those of the other Ganoids, and impress the observer with their marked Teleostean characters. They are readily reduced to the plan of those of Lepidosteus; and the accompanying figures (Pl. 30, figs. 1—9) may be instructively compared with those in the 'Journal of Morphology,' vol. xi, pl. i, figs. 1—9. And, on the other hand, they closely suggest the plan of segmentation of the Teleost, e.g. that of Serranus.[1] In the following description, accordingly, it will be the writer's purpose to emphasise these more important comparisons.

In general it may be said that the egg of Amia is meroblastic, that its (earlier) cleavages are confined entirely to the germinal area, that the compact blastomeres are Teleost-like, and that the segmentation cavity is practically wanting.

First Cleavage (Pl. 30, fig. 2).—In the living egg the first cleavage passes at once vertically through the germ area, causing the resulting blastomeres to be closely opposed. In the preserved material, however, the rim of contact (as in Pl. 30, fig. 3) appears somewhat rounded. At this stage the lower rim of the germ disc presents a more definite line of contact with the yolk, and the cleavage plane rounds off the corners of the blastomeres. In the transverse vertical section shown in Pl. 31, fig. 21, are illustrated the depth and the character of the cleavage plane; it has passed slightly deeper than the niveau of the nuclei, but leaves below it a well-marked layer of the germinal protoplasm; the germ disc in this region has become slightly deeper. The first cleavage was observed in several instances to divide the germ disc into blastomeres of unequal size; this abnormality, however, as in Lepidosteus,[1] Teleosts,[2] as well as in other Chordates, was found to in no way influence the subsequent developmental stages.

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[1] H. V. Wilson, "The Embryology of Serranus atrarius," 'Bull. U.S. Fish Comm.,' 1891, pp. 209—277.

The writer, it might be here noted, has taken especial care to verify his observations on the meroblastic character of the cleavages of Amia. During the first few cleavages several hundred living eggs were examined with a view of determining holoblastic variations. These, however, did not occur, nor were there found even by the most favorable means of illumination, traces of what might be construed as surface furrows traversing the yolk region of the egg. In no case did a marginal cleavage pass below the rim of the germinal disc.[3]

Second Cleavage (Pl. 30, fig. 3) passes in a vertical plane at right angles to the first cleavage. This it closely resembles in depth and marginal limits; and in this stage the nuclei retain the same niveau with similar relations to the yolk. Immediately below animal pole the blastomeres slightly separate, giving rise to the beginnings of the segmentation cavity. In an examination of a number of eggs at this stage but very few (2 per cent.) variations were observed, the second plane in these cases intersecting the first at an angle of about 70°. Polflucht was in no instance noteworthy.

Third Cleavage (Pl. 30, fig. 4).—This cleavage plane is again vertical, and, as in Lepidosteus and Teleosts, at right angles to the preceding plane (i. e. parallel to the first cleavage). In this stage variations were found to be common (20 per cent.),

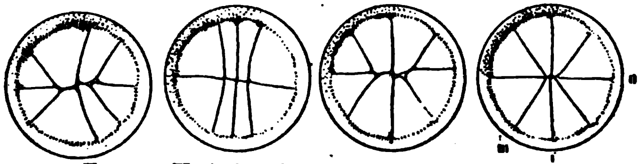

FIG. 5.—Variations in the stage of third cleavage.

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[1] Dean, op. cit., p. 16.

[2] Ryder (cod), H. V. Wilson (Serranus), Whitman, and others.

[3] Cf. the somewhat different view of Fülleborn, op. cit., p. 1061.

and noteworthy Polflucht occurred. Several variations are shown in the adjoining figure (Fig. 5), of which the most frequent, as in Lepidosteus, is the symmetrical meridional form shown at the left. The segmentation cavity takes its definite origin at this stage; in the region of the animal pole the blastomeres are separated from the underlying yolk—the germ disc by a narrow fissure, which has been found to arise in the cleavage planes of the animal pole. Thus in a section of the germ disc passing through the points *—* of Pl. 30, fig. 4, it will be seen (Pl. 31, fig. 23) that the blastomere, which is cut nearly transversely (*a*), is separated below from the yolk region of the germ disc (*yg.*) ,and at the sides partly, from the adjacent blastomeres by the fissure-like segmentation cavity (*sc.*). And it will be further noted that the yolk region of the germ disc (*yg.*) is still in common, marginally, with the blastomeres. With these conditions should be contrasted the more shark-like features of the corresponding stage of Lepidosteus (Dean, op. cit., p. 17, and pl. ii, fig. 26).

Fourth Cleavage (Pl. 30, fig. 5).—The plane of the fourth cleavage is again vertical, resembling the third cleavage in essential regards. Its general direction is parallel to the second cleavage. This stage usually results in the division of the germ area into blastomeres of approximately equal size; often, however, as in the figure (Pl. 30, fig. 5), the cleavage passes nearer or further from the animal pole than in the preceding stage: in this event the central blastomeres appear at the surface rectangular instead of square. Many cleavage variations at this stage were recorded, in which noteworthy Polflucht occurred, and in which meridional planes often replaced the transverse cleavages; in no instance, however, were horizontal cleavages observed. The segmentation cavity in this stage does not markedly differ from that noted in the earlier stage. In Pl. 31, fig. 24, a section is shown passing through the central blastomeres in the direction of the (first or) second cleavage plane; its direction is slightly oblique, and it is for this reason that five blastomeres appear. In this section the extent of the segmentation cavity may be followed, and by a study of serial sections it may be determined that the central blastomeres are now separate from the underlying germ-yolk, but that the marginal blastomeres are unseparated from it; the nuclei still remain in the low region of the blastomeres. The dilated spaces separating the sides of the blastomeres might perhaps be regarded as artefacts.

Fifth Cleavage (Pl. 30, fig. 6).—The stage of thirty-two cells is the first in which horizontal cleavages have been noted. These occur, however, only by variations in the divisions of the central blastomeres, and are by no means common. The typical conditions of this stage are shown in the above figure. From the study of living eggs the fifth cleavage was observed to take place in the following manner:—The five central blastomeres of the sixteen cells divide vertically in somewhat meridional planes, forming together a compact mass in the region of the animal pole, separated from the marginal blastomeres by a sharply cut trench; a few minutes later the marginal blastomeres undergo vertical division in meridional planes. That this is the normal plan of cleavage has been verified by serial sections of the late sixteen-cell stages where the nuclear figures have been clearly followed. Thus it appears that there occurs a noteworthy difference from the normal mode of the fifth cleavage in Lepidosteus (Dean, op. cit., p. 17). Variations, however, are numerous; the horizontal cleavage of the central blastomeres has been already noted, and the tendency of the cleavage planes of the marginal blastomeres to pass obliquely seems to suggest an approach to the conditions of the gar-pike. This cleavage of Amia, therefore, is not as nearly of the Teleostean plan as in the latter form. An interesting condition in this stage is the mode of origin of the newly formed marginal blastomeres; these appear to be budded out directly from the germ-yolk (Pl. 31, fig. 25, *gyb.*), their nuclei at first lying below the plane of the segmentation cavity; the central blastomeres as before are separated from the germ-yolk by the segmentation cavity.

Sixth Cleavage (Pl. 30, fig. 7).—The lineage of the cells of this stage could not be definitely followed; numberless variations were found, and every attempt to reduce them to a common type was unavailing. Numerous horizontal cleavages occur in all blastomeres; increments to the cell disc are not lacking from the floor of the segmentation cavity. In the section in Pl. 31, fig. 26, a cell is seen to be budding out of the germ-yolk region at *m*, and at *m′* a dividing nucleus in the same region is clearly comparable to a merocyte. A study of living material demonstrates one of the steps in the transition from the fifth cleavage, i.e. the usual mode of division of the marginal blastomeres. These may be seen to bud off their polar ends, which, in turn, join the central cell mass, and leave as their outer boundary a furrow similar to that outlining the central blastomeres in the preceding stage. It is evident from the section of Pl. 31, fig. 26, that the area of the segmentation cavity, *sc.*, has greatly enlarged, although as a cavity it is no longer marked as in Pl. 31, fig. 25; the blastomeres are now directly apposed to the germ-yolk area.

Seventh Cleavage (Pl. 30, fig. 8).—Horizontal and vertical cleavage planes pass irregularly through the cells of the germinal disc. Nuclei occur (Pl. 31, fig. 27) in the germ-yolk area (*m, m, m.*) and bud off blastomeres to the overlying cell disc, and are seen to be undergoing direct division. The segmentation cavity (*sc.*) has now a flooring of a single layer of irregular blastomeres derived mainly from the germinal yolk.

Eighth Cleavage (Pl. 30, fig. 9).—By this stage the blastomeres have so subdivided that in surface view they can be but obscurely defined; marginally, however, they extend no further than in the earlier cleavages. Sections of this stage show that the cell-cap has increased in thickness (Pl. 31, fig. 28); a number of irregular blastomeres, yolk-laden, are seen in process of being budded off from the floor of the segmentation cavity, and numerous yolk nuclei are apparent. The segmentation cavity (*sc.*) extends irregularly among the blastomeres.

Subsequent stages of segmentation correspond closely with that last described, the blastomeres continuing to subdivide, and at the same time to encroach slowly on the yolk region of the egg.

D. **Blastula.**—A typical stage of the blastula is figured in vertical section in Pl. 31, fig. 29, and a somewhat later stage in surface view in Pl. 30, fig. 10, and in section in Pl. 31, fig. 30. The latter, contrasted with the sections of figs. 28 and 29, indicates clearly the downgrowth and the greater depth of the blastoderm; its cells have greatly increased in number, and build a dome-shaped cell cap of nearly twice the thickness of that of fig. 28; its cells are small, spherical, and of uniform size; those of the surface layer, however, have compacted into a firm cell stratum, *e′*, and those in the lowermost part of the blastoderm are slightly larger, yolk-laden. In this region the space between the loosely associated cells (*sc.*) is evidently to be compared with that (*sc.*) of the former figures. The segmentation cavity will be noted to extend irregularly between the blastomeres as far as the outermost cell stratum. Its floor is flattened, and bears a tier or more of irregular, upwardly projecting yolk-cells, and below them a merocyte-bearing zone of yolk.

The conditions of the blastula of Amia present interesting resemblances to those of Lepidosteus, and especially to those of the Teleosts.

The resemblances to the Teleostean blastula (e. g. cf. H. V. Wilson, op. cit., fig. 27) include—the lenticular shape of the blastoderm, the general uniformity of its elements, the differentiation of the outermost cell strrtum, the apparent relations of the yolk nuclei to mode of growth of the blastoderm. In the latter regard it cannot be doubted that the closest functional kinships to the periblast are present; cell increments are being constantly made in the plane of the base of the blastoderm through the agency of a layer of nucleated elements derived from the yolk region.

E. **Gastrula.**—Typical conditions of the gastrula have been figured in surface views in Pl. 30, figs. 12, 13; an early stage in fig. 11, and two of the closing stages in figs. 14, 15. Like the blastula, it proves of considerable interest in comparison with the conditions of the older Ganoids on the one hand, and of the Teleosts on the other.

The transition from the stage last described to that of the early gastrulation may first, however, be followed. In Pl. 30, fig. 10, is figured in surface view a late blastula; the light coloured dome-shaped blastoderm appears sharply marked off from the yolk; its marginal rim, as a somewhat irregular line, seems as if in bold relief against a somewhat dark-coloured zone of the yolk; in surface view, in fact, it appears to overhang the yolk, and thus to represent the beginnings of gastrulation. That this observation, however, is incorrect is demonstrated both by sections and by a closer examination of the surface view of the object; the darker colour of the yolk zone is probably due to its merocyte-bearing character. It is in the stage figured in Pl. 30, fig. 11, that gastrulation actually begins. The downgrowth of the blastoderm is accompanied by the slight overlapping of its rim at one side—at the left in the figure; the remainder of the clearly defined margin has not as yet separated from the yolk. By the stage of Pl. 30, fig. 12, the downgrowth of the blastoderm has separated its entire rim from the yolk; and that portion which initiated the process of separation is now separated most widely as the dorsal lip of the blastopore. This region at a very similar stage has been shown in the following figure, Pl. 30, fig. 13, as exhibiting a variation[1] of considerable interest; at the rim's dorsalmost point a slight indentation is present, which may be supposed to correspond to the true blastopore of the ancestral Ganoid and Elasmobranch, the remaining portion of the rim representing the circumcrescence margin (O. Hertwig).

Later surface views of the gastrula are seen in Pl. 30, figs. 14, 15. In the former the continued growth of the blastoderm has greatly reduced the size of the blastopore; this now appears as a circular opening, its margin slightly nicked on both ventral and dorsal sides, and shows dorsally the whitened tract which marks the appearance of the embryo. In the latter is figured the stage of the closing blastopore; the embryo is here faintly outlined as a white flattened cell mass; at its hindmost region the blastopore, as a funnel-shaped pit, is enclosed by its thickened and constricting margin.

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[1] Variations in the outline of the closing blastopore are not uncommon (cf. Lepidosteus, Dean, op. cit., p. 22). Oval blastopores were noted: in some one or both of the marginal indentations had disappeared; the dorsal one, however, is usually persistent.

It is, however, from the study of gastrulæ in sagittal sections that the most interesting comparisons may be made with the conditions in gar-pike, sturgeon, and Teleosts. Some of these have been figured in Pl. 32, figs. 31 (=Pl. 30, fig. 11); 32 (=Pl. 30, fig. 12); 33 (=Pl. 30, fig. 14); 34 (slightly earlier than Pl. 30, fig. 15). But before comparisons may be established, the advancing changes should briefly be reviewed. The early gastrula, Pl. 32, fig. 31, it is to be noted, occupies approximately the area of the egg's surface as the blastula of Pl. 31, fig. 30; it has, however, the following advancing characters:—the loose cells of the blastoderm, now of minute size, have flattened into a compact cell mass, ectoblast (*o*) still presenting a well-marked surface layer (*o′*); the segmentation cavity (*sc.*) has accordingly become greatly depressed, and is now fissure-like; below it are several tiers of loosely compacted cells, which, by regular transition, appear to take their origin in large, vaguely defined yolk cells (*yc.*) arising from merocytes (*m′*); the rim of the blastoderm at *dl.* is the region where the blastoderm is early separated from the yolk; there is here, however, no cavity apparent separating the dorsal lip of the blastopore (*dl.*) from the yolk (*y.*); both are closely apposed, and at the point * their elements can no longer be distinguished; the entoblast (*i.*), arising from the undifferentiated tissue of the dorsal lip, is here composed of compact elements, but in the central region of the blastoderm becomes equivalent to the loose cellular layer already noted as continuous with yolk-cells and merocytes; at the opposite point of the blastoderm's margin, the blastopore's ventral lip, no separation of the germ layers from the yolk has as yet occurred.

In a following stage (Pl. 32, fig. 32) the blastoderm is shown enclosing about 285° of the egg's vertical circumference. The ectoblast has greatly thinned out, is thickest at its perimeter and at its dorsal lip; the segmentation cavity is fissure-like;

the ventral lip of the blastopore is now separate from the yolk, but is closely apposed to it, as in the case of the dorsal lip, making the cœlenteron (*c.*) fissure-like; the inner germ layer is in contact with the yolk-cells near the point; * in the central region of the blastoderm it no longer exhibits the entoblast cells; their well-marked layer has apparently become merged with the yolk-cells.[1]

In a still later gastrula (Pl. 32, fig. 33) the growth changes include:—the greater thickness of the lips of the blastopore, the retraction of the yolk-mass, the appearance of the cœlenteron as a distinct cavity (*c.*) and its extension forward under the dorsal lip (as far as the point *), the origin of the ectoblastic head mass, and of the middle germ layer. In the last regard this stage merits special attention: the mesoblast is found to arise peristomal (*m.*); on the dorsal side it arises from the undifferentiated tissue (of the tail mass), thence extends forward as a separate cell layer, and finally appears to be blended with the loosely associated cells of the entoblast; ventrally the mesoderm (*m.*), although distinctly to be recognised, is not to be separated from the cellular elements of the entoderm.

And finally, in the stage of the closing blastopore (Pl. 32, fig. 34), the embryo having surrounded about 180° of the egg's circumference, the following characters appear:—The greatly increased size of the ectoblastic head mass (*h.*), and of the cœlenteron (*c.*) together with the complete differentiation beneath the embryo of the middle germ layer (*m.*). The latter appears to have been differentiated in situ from the loosely associated cell mass shown in the preceding figure; it is separate anteriorly as far as the region immediately below the head terminal. The cœlenteron, now a deep cavity beneath the dorsal lip, extends forwards below the entire head; its hinder dilation (*k.*), immediately below the dorsal lip, is to be interpreted as representing Kupffer's vesicle;[1] beneath the ven-

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[1] No critical attempt has ever been made to follow the actual mode of the growth of the embryo, as, for example, has been done by Morgan in the case of Ctenolabrus (1895, 'Journal of Morphology,' vol. x, No. 2).

[2] Dean, op. cit., p. 42.

Figs. 6—13.

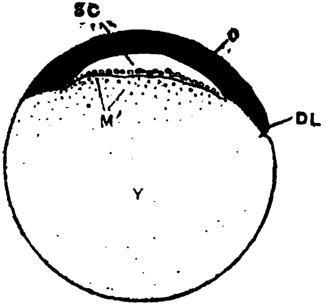

Fig. 6.

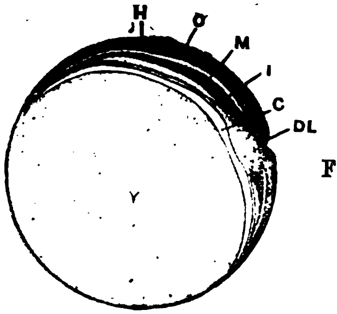

Fig. 7.

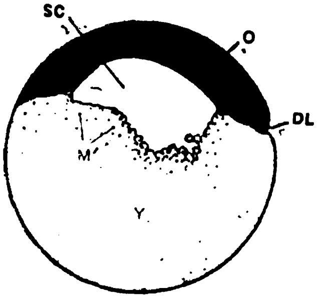

Fig. 8.

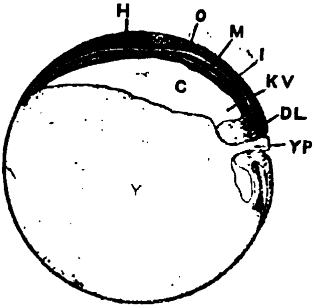

Fig. 9.

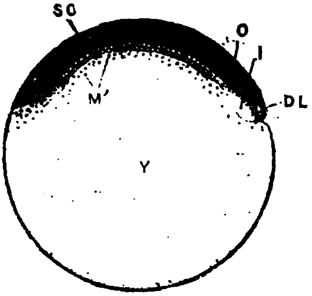

Fig. 10.

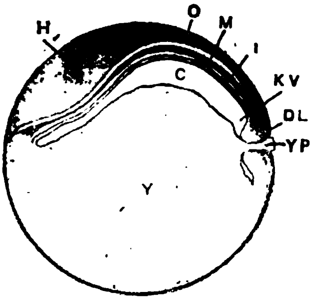

Fig. 11.

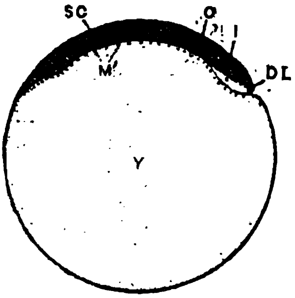

Fig. 12.

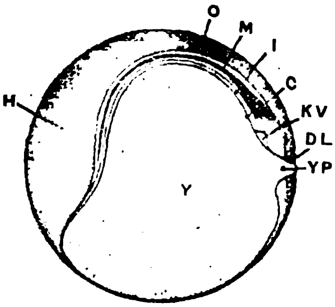

Fig. 13.

Sagittal sections of early and late gastrulæ of Ganoids and Teleosts. 6, 7. Lepidosteus. (In Fig. 7 the blastopore has just closed.) 8, 9. Acipenser. 10, 11. Amia. 12, 13. Teleost. c. Cœlenteron. DL. Dorsal lip of blastopore. H. Head (= cephalic thickening of neuron). I. Inner germ layer. KV. Kupffer's vesicle. M. Middle germ layer. M′. Merocytes (= periblast in Fig. 12). O. outer germ layer. SC. Segmentation cavity. Y. Yolk region. YP. Yolk plug.

A Comparison of the Gastrulation of Lepidosteus, Acipenser, Amia, and Teleost (cf. figs. 6—13).

	LEPIDOSTEUS.	ACIPENSER.	AMIA.	TELEOST.
EARLY GASTRULA. Dorsal lip of blastopore appearing.	Surrounds about 160° of the egg's circumference. Well-marked meniscus-shaped segmentation cavity, with a smooth flooring of merocyte-yolk, overlaid by an irregular tier of loosely associated entoblast cells. Entoblast of dorsal lip undifferentiated.	Surrounds about 170°. Segmentation cavity large, deep, irregular; its roof thick, its flooring of loosely associated cells merging gradually into the yolk. Entoblast of dorsal lip undifferentiated.	Surrounds about 150°. Segmentation cavity flattened, fissure-like, its roof slightly thicker (relatively) and its elements larger than in L.; its floor a double tier of loosely associated cells, with below a yolk-cell zone. Entoblast of dorsal lip cannot well be distinguished from the loosely associated cells of the floor of the segmentation cavity, i. e. cœlenteron tends to merge with segmentation cavity.	Surrounds about 90°. Segmentation cavity flattened, fissure-like; its roof slightly thicker (relatively) and its cellular elements larger than in Am., its floor a smooth merocyte-bearing yolk layer (= periblast = tier of loose associated cells of Am.). Entoblast of dorsal lip closely apposed to, but now separate from periblast; cœlenteron merges, therefore, with segmentation cavity.
LATE GASTRULA. Blastopore closing.	Germ layers of nearly uniform size and thickness. Cœlenteron flattened, extending far forwards and also notably under ventral lip. Randwulst not marked. Embryo hardly noticeable (surrounds 90°). Mesoblast appears late, peristomal and gastral.	Outer germ layer thickest. Cœlenteron deep, extends anteriorly in front of the head region, but does not extend far under the ventral lip. Randwulst greatly marked (Kupffer's vesicle appearing). Embryo noticeable (surrounds 110°). Mesoblast appears early, largely peristomal.	Outer germ layer thickest, deepening in the sagittal plane. Cœlenteron flatter than in Ac., extends not as far forward or hindward. Randwulst not as marked as in Ac. (Kupffer's vesicle appearing). Embryo more noticeable (surrounds 190°). Mesoblast appears earlier, and is (very largely, if not entirely) peristomal. But two germ layers clearly distinguishable in ventral lip.	Outer germ layer very thick in the sagittal plane. Cœlenteron flattened between embryo and yolk, appearing as a cavity only under the dorsal Randwulst, which is now less prominent than in Am. as Kupffer's vesicle. Embryo well marked (surrounds 220°). Mesoblast (probably) peristomal. Layers undifferentiated in ventral lip.

tral lip the cœlenteron is no longer prominent. The closure of the blastopore is effected very much as in Lepidosteus or Acipenser, the constricting of its margin is the apparent cause of a greatly enlarged Randwulst; this ingrowth is attended by the protrusion of a slender yolk-plug (*yp.*), which on the blastopore's closure appears to be largely withdrawn.

A comparison of the gastrulation of Amia with similar stages of kindred forms may now be made. And this will be seen to become of especial interest since the intermediate characters of its gastrulation enable a far clearer understanding of this complicated growth stage of fishes than has yet been given. On the one hand the gastrula of Amia present decidedly Ganoidean features, while on the other its structures are clearly to be compared with those of the Teleost. An accompanying series of figures (figs. 6—13) enables comparisons to be more readily drawn; they present sections (nearly sagittal) of the earliest and of the latest stages of the gastrula of Lepidosteus, Acipenser, Amia, and Teleost; in the earliest stages the dorsal lip is coming to be formed; in the latest, the blastopore is closing.

From the foregoing comparison it seems to the writer evident that well-marked transition exists in the structures of corresponding stages. These he believes may, as in his figures, most conveniently be followed, starting with the archaic plan of gastrulation of Lepidosteus, passing to that (somewhat divergent) of the ancient sturgeon, thence to the more modern type of Amia, and finally to that of the highly specialised and recent Teleost. And it seems clear to him, furthermore, that the puzzling features of the gastrula of the specialised bony fishes (Teleocephali) may be interpreted as altogether due to a process of advancing or accelerated (precocious) development. Thus the advancing growth changes appear to be indicated in the following processes.

1. The invagination tends to begin at an earlier stage when the blastodisc covers a smaller area of the egg's surface, and the elements of the early gastrula tend to become relatively larger, and the roof of the segmentation cavity relatively thicker.

2. The segmentation cavity tends to become flattened and to recede centrad.

3. The embryo tends to become larger, and its structures more precociously differentiated, concentrating its substance more and more early in the sagittal plane of the dorsal lip (and leaving, therefore, the remaining region—e. g. ventral lip undifferentiated), and growing notably in the head region.

4. The embryo, pari passu with its more precocious development, has come to acquire more perfect relations with the yolk. The growth of the embryo in the generalised condition is derived from deep merocyte layers of the yolk; in the more specialised conditions, however, the more peripheral layers of deutoplasm become of service. Cellular increment is derived in Amia from a double tier of cellular zone of the floor of the segmentation cavity, which in the Teleost becomes clearly homologous with the periblast. In such an event the cœlenteron becomes clearly confluent with the segmentation cavity.

From the foregoing discussion the writer's views as to the homologies of the structures of the Teleostean gastrula are clearly apparent; and they will be found to correspond with those which he had formerly expressed in his paper on the gar-pike and sturgeon (p. 52). His interpretation requires, accordingly, the Ziegler-Wilson conception of the gastrula to become modified as follows:[1]—The cœlenteron extends under the rim of the blastoderm, from the free end of the "primitive hypoblast" to that of the "ventral mesoderm" of H. V. Wilson, the periblast yolk losing its ancestral cellular connection with the embryo, on account of acquiring its indirect but more highly important (and specialised) method of furnishing its cellular increments.

F. The Mode of Formation of the Embryo.—The embryo has already made its appearance by the time of the closure of the blastopore. It is there recognised in the flattened and opaque cell mass extending in front of the blastopore, and enclosing about 180° of the egg's circumference (Pl. 30, fig. 15, and Pl. 32, fig. 34). Its substance is insunken in the egg.

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[1] H. V. Wilson, op. cit., p. 264.

The mode of establishment of the early embryo's outward form may be followed in Pl. 30, figs. 16—20. In the first of these figures (fig. 16) the embryo surrounds about 185° of the egg's circumference, and the blastopore has disappeared; a whitened line on the egg's surface represents the neural axis, its enlarged terminal the brain tract; a slight darkening in the axial line is due to a shallow trench-like insinking of the neural plate. The embryo is not as yet noticeable above the surface curvature of the egg. In Pl. 30, figs. 17 and 18, the head and tail regions of a slightly older stage, the following changes have taken place:—The embryo, a rod-like surface thickening, surrounds about 195° of the egg's circumference; its head, prominent and enlarged, rises slightly above the surface curvature of the egg; its trunk tapers hindward, ridge-like in form, closely apposed to and slightly insunken in the egg mass; two mesoblastic somites have appeared. In the stage of Pl. 30, figs. 19 and 20, six somites are present, and the embryo has enclosed about 220° of the egg's circumference; the neural axis, now more sharply marked, rises slightly above the egg; the tail in its growth is now separating from the egg surface; the brain regions are defined, optic vesicles are appearing; and the head region, growing slightly forward, has in front the beginnings of the stomodæum.

In the features of early outward growth Amia again presents marked transitional characters between Ganoids and Teleosts. Like the latter, its form growth is early concentrated in the sagittal plane, and the embryo deeply sunken in the egg mass. It later resembles the Ganoids in its uplifting from the yolk and in the details of organogeny. A few further notes regarding the origin and growth of its structures are given in the following section.

G. The Origin and Early Differentiation of the Germ Layers.—The outer germ layer has been already noted (p. 19) in the early gastrula as a compact cell mass of comparatively uniform thickness. Its subsequent growth has also been reviewed in the table and figures of pp. 21, 22. By the time of the blastopore's closure it has given rise to the sagittal thickening out of which the central nervous system is shortly to be formed. This, in its early characters, suggests closely the neuron of the Teleost (Pl. 32, figs. 34 and [transverse section] 36). Its deep keel-like thickening resembles closely as well the earliest conditions of Lepidosteus, while diverging from the type of Acipenser. To the conditions in this form, however, an apparent similarity exists in the stage already noted in Pl. 30, fig. 16, where a slight axial groove is for a short time present; this condition, of interest, accordingly, from its sturgeon-like feature, is further illustrated in the transverse section of Pl. 32, fig. 37; the axial groove is never deeper than here figured, and shortly passes away, flattening as the neuron increases in size and depth. The lumen which the neuron later acquires takes its definite origin in the dissociation of cells in the vertical plane of its axis (Pl. 32, fig. 39). This condition is clearly to be compared with that of the Teleost, as described by Hoffman, v. Kupffer, H. V. Wilson, and others. It might, moreover, be regarded as confirming conclusively the position of v. Kupffer in regard to the morphological importance of the neural furrow of the Teleost, i. e. that it is homologous to the primitive neural furrow of Amniotes; and, on the other hand, it certainly removes the ground for believing that the neural axis of the Teleost was primitively solid, as Minot has maintained.[1] For there can be little doubt that Elasmobranchian characters are present in the origin of the neuron of Acipenser, and it follows, therefore, that the neural furrow of Amia, its ally, must represent, if only in a transient way, the early Amniote condition. In the Teleost, accordingly, it is reasonable to expect that abbreviated growth stages have greatly reduced the prominence of the ancestral medullary folds, while perfecting the newly acquired mode of securing a neural canal.

A further and striking similarity to Teleostean conditions is found in Amia in the early development of the optic vesicles.

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[1] 'American Naturalist,' November, 1889.

Absence of neurenteric canal is, again, Teleostean. In this regard its features are notably transitional between those of Lepidosteus and the Teleost. At the closure of the blastopore, Pl. 32, fig. 35, there is no trace of the neural groove in the hinder region, the outer germ layer here fusing in a solid plug, merging below into the undifferentiated tissue, *u*; at a later stage, Pl. 32, fig. 38 (cf. H. V. Wilson, op. cit., pl. xcviii, fig. 84), the ventral lip of the blastopore has become largely merged with the growing tissue, *u*, of the tail region, and the conditions are markedly Teleostean.

The inner germ layer has already been noted (p. 19) in its intimate relationship to the yolk mass. In Pl. 32, fig. 31, the entoderm is clearly defined, extending forward from the rim of the dorsal lip to about the position of the point*, having in its texture all the characters of the similar stage in gar-pike and sturgeon. Beyond this point, however, it merges into the loose layer noted on p. 19, whose periblast-like characters have already been indicated (p. 22). The growth in extent of the entoderm may be followed in Pl. 32, figs. 31—36, 38, 39; under the ventral lip of the blastopore it appears for a short distance (fig. 35) as a separate layer, but in a later stage (fig. 39) it becomes merged with the yolk entoblast; under the blastopore's dorsal lip the darm-entoblast has separated from the yolk region (apparently by differentiation of the cells in situ) as far as the point * in fig. 33, and as far as the most anterior head region in fig. 34; at its periphery the cells become indistinguishable from those of the neighbouring yolk. The gut arises in a manner closely resembling that of Acipenser; its cavity, narrow and deep (fig. 34) tailward, flattens out broadly in the head region, as is shown in the marginal limits of the parietal zone of Pl. 30, figs. 17—20; its mode of formation, it should be noted, although of clearly marked Ganoidean character, diverges, nevertheless, toward the plan of the Teleost; it has not, however, acquired the yolk-apposed characters of the latter. The notochord arises as in the sturgeon or gar-pike (Pl. 32, fig. 38): it separates directly (i. e. delaminates) from the entoderm; in the region of the hind brain, as seen in

Pl. 32, fig. 36, it is undifferentiated from the loosely associated cells of the lower layer.

The mesoblast is notably peristomal (Pl. 32, figs. 33—36, 38, 39); it is hardly to be distingushed in the blastopore's ventral lip (cf. figs. 35, 39): its appearance is first noted in the gastrula of fig. 33. In its early growth it extends forward as a wide and flattened cell mass, thinning distally, and becoming confluent with the inner germ layer. As in the Teleosts, gastral mesoderm is absent, and the division of the middle layer into its somatic and splanchnic layers is not apparent until comparatively a late stage of development. A contrast with the conditions of the mesoblast in Acipenser and gar-pike may be made by reference to the table in Dean, op. cit., p. 47.

III. Conclusions.

The early development of Amia, as outlined in the foregoing paper, must certainly be regarded as furnishing abundant evidence of intermediate characters. To the Ganoids on the one hand, and the Teleosts on the other, these ontogenetic nearnesses become, accordingly, of the greatest interest, since they confirm the results of the structural study of recent and fossil forms upon the Amioid descent of Teleosts.

A comparison of the developmental characters of Amia with those of the gar-pike and sturgeon need be but briefly reviewed. Its type of development is in many ways curiously Lepidosteoid, as in meroblastic segmentation, relations of blastoderm to yolk, flattened segmentation cavity, late gastrulation, early neuron, and absence of neurenteric canal. It certainly resembles that of the sturgeon in some of its advancing characters, as in the mode of closure of the blastopore, decreased prominence of its ventral lip, and in the embryo's sagitally accented growth. From either of these older Ganoids the developmental type of Amia is nevertheless sufficiently different to warrant any definite conclusions as to its descent; one might, the present writer believes, safely infer that, like that of the sturgeon, it is in general Lepidosteoid.

But the early development of Amia is clearly to be recognised as of an advancing type. It bridges over in many and important characters the gap which has always been pointed out as separating the Ganoids and the Teleosts. Its abbreviated development indicates, in short, the very stages which are most abbreviated in the cænogenesis of the latter group. Its meroblastic mode of cleavage is decidedly Teleostean, especially in the relations of its segmentation cavity and yolk nuclei, although in these regards it also closely resembles Lepidosteus. Its transitional characters are most clearly marked during gastrulation, and during the early growth of the embryo. These Teleostean features might, in conclusion, be briefly summarised.

Small area of blastoderm at the beginning of invagination (?). Flattened segmentation cavity. Early relations of inner germ layer of dorsal lip with periblast-like conditions of the yolk cells; cœlenteron is then practically confluent with the segmentation cavity. General thinness of the down-growing blastoderm, whose Randwulst corresponds to the germ-ring; close apposition of blastoderm to yolk mass. Early appearance of the embryo; and in general early differentiation of the germ layers of the blastopore's dorsal lip, attended by a corresponding lack of differentiation of the ventral lip. The mode of the closure of the blastopore; the presence of Kupffer's vesicle and the absence of neurenteric canal. The early growth of the neuron as an insunken tract thickest in the sagittal plane. The early prominence of the brain mass. The evanescent medullary groove; the solid character of the early neuron, and its secondary mode of acquiring a neural canal. The peristomal mode of origin of the mesoblast; its late differentiation; the absence of gastral mesoblast. The early mode of establishment of the embryo's outward form.

EXPLANATION OF PLATES 30—32,

Illustrating Dr. Bashford Dean's paper on "The Early Development of Amia."

PLATE 30.

Figs. 1, 2, 4, 15, 19, and 20 drawn by Bashford Dean from the living eggs, the remaining figures from eggs hardened in alcoholic (50 per cent.) picro-sulphuric mixture, by Dr. Arnold Graf. × about 50.

Fig. 1.—Living egg shortly before the appearance of the first cleavage furrow. About ½ hour after fertilisation.

Fig. 2.—First cleavage; it sharply separates the halves of the germ-disc, but extends no further marginally than its limits. 1 hour.

Fig. 3.—Second cleavage, seen from above. 2 hours.

Fig. 4.—Third cleavage; similar in marginal extension to the first and second. 3 hours.

Fig. 5.—Fourth cleavage, 4½ hours.

Fig. 6.—Fifth cleavage, 5½ hours.

Fig. 7.—Sixth cleavage, 6½ hours.

Fig. 8.—Seventh cleavage, 7½ hours.

Fig. 9.—Eighth cleavage (early blastula), 8½ hours.

Fig. 10.—Early gastrula, 46 hours.

Fig. 11.—Early gastrula, 48 hours.

Fig. 12.—Gastrula, about 50 hours.

Fig. 13.—Gastrula showing indented rim of blastopore at the dorsal lip. 54 hours.

Fig. 14.—Late gastrula, showing mode of closure of the blastopore; the embryo's appearance is faintly indicated in the light-coloured area immediately above the centre of the figure. 71 hours.

Fig. 15.—Closure of the blastopore, and the appearance of the embryo. 78 hours.

Fig. 16.—Early embryo showing neural folds; its length surrounds about 185° of the egg's circumference. About 93 hours.

Fig. 17.—Early embryo, showing head region; its length surrounds about 195° of the egg's circumference. Two somites present. 95 hours.

Fig. 18.—Early embryo; tail region of embryo of Fig. 17.

Fig. 19.—Early embryo showing head region; its length surrounds about 220° of the egg's circumference. Six somites present. 100 hours.

Fig. 20.—Early embryo; tail region of embryo of fig. 19.

PLATE 31.

Vertical sections of cleavage stages and of blastula. × about 55.

Fig. 21.—Second cleavage; sectioned parallel to a cleavage plane through the resting nuclei.

Fig. 22.—Third cleavage; sectioned near and parallel to the plane of the second cleavage.

Fig. 23.—Third cleavage; sectioned in a plane passing through the points *—* of Pl. 1, fig. 4.

Fig. 24.—Fourth cleavage; sectioned in a plane (slightly oblique) near and parallel to the first (or second) cleavage.

Fig. 25.—Fifth cleavage.

Fig. 26.—Sixth cleavage.

Fig. 27.—Seventh cleavage.

Fig. 28.—Eighth cleavage.

Fig. 29.—Early blastula. Eleven hours after first cleavage.

Fig. 30.—Blastula. Thirty-three hours after first cleavage.

a. Central blastomere. *e*. Entoblast. *e′*. Epidermic stratum of ectoblast. *gyb*. Germ yolk blastomere. *m*. Merocyte. *m′*. Blastomere arising from merocyte-bearing germ-yolk. *n*. Nucleus. *sc*. Segmentation cavity. *y*. Yolk. *yg*. Germ-yolk.

PLATE 32.

Vertical sections of gastrulation stages and of early embryos.

Fig. 31.—Early gastrula (47 hours), nearly sagittal section. × 35.

Fig. 32.—Gastrula (50 hours), nearly sagittal section.

Fig. 33.—Gastrula (55 hours), nearly sagittal section.

Fig. 34.—Late gastrula (or early embryo) (75 hours), nearly sagittal section.

Fig. 35.—Early embryo (78 hours); section slightly oblique to embryo's axis, passing through the region of the closed blastopore. × about 70.

Fig. 36.—Early embryo (78 hours); transverse section passing through the region of the hind brain. × about 70.

FIG. 37.—Early embryo (77 hours); transverse section of neuron of the hinder trunk. × about 160.

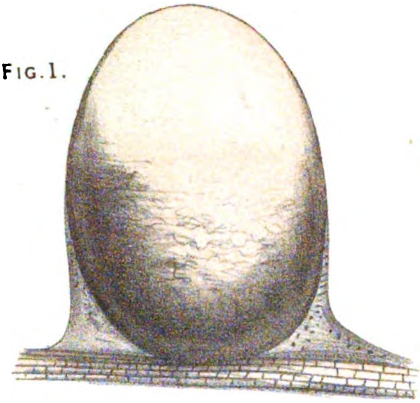
FIG. 38.—Early embryo (95 hours), transverse section; somewhat in front of the undifferentiated tissue of the tail mass.

FIG. 39.—Early embryo (95 hours), sagittal section of the region of the closed blastopore. × about 80.

FIG. 40.—Early embryo (95 hours); transverse section of neuron in a region somewhat behind the hind brain.

c. Cœlenteron. *ch*. Notochord. *dl*. Dorsal lip of blastopore. *h*. Head region (of neuron). *i*. Inner germ layer. *k*. Kupffer's vesicle. *m*. Middle germ layer. *m'*. Merocyte. *o*. Outer germ layer. *o'*. Epidermic stratum of the outer germ layer. *sc*. Segmentation cavity. *u*. Undifferentiated tissue of the lip of blastopore. *vl*. Ventral lip of blastopore. *yp*. Yolk-plug. * denotes the innermost limit of cœlenteron.

Fig. 1.



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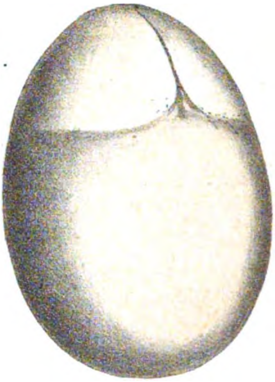

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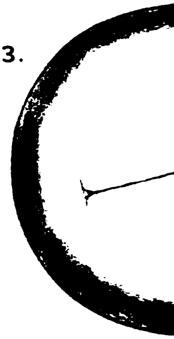

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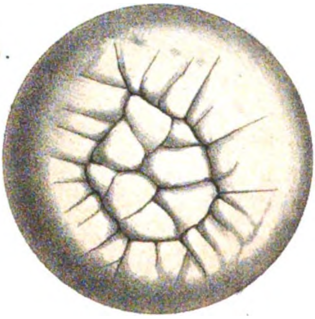

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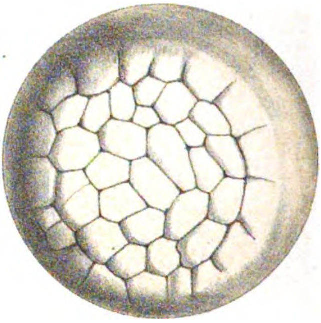

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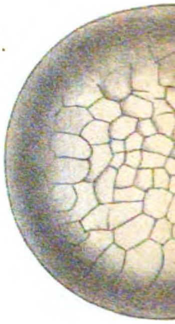

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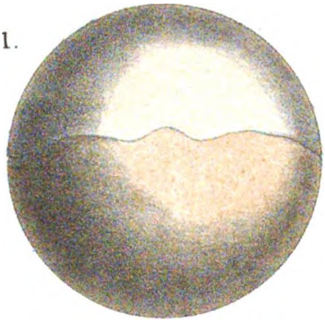

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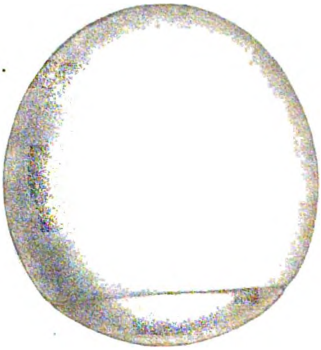

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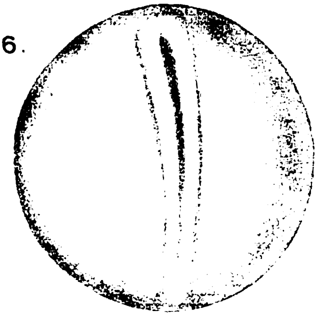

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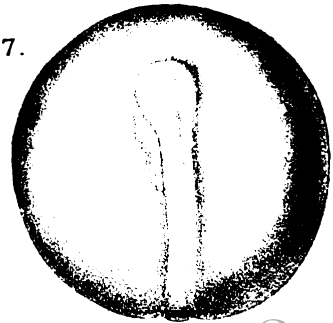

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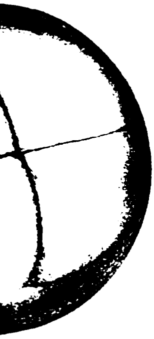

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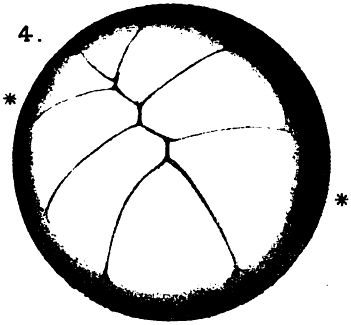

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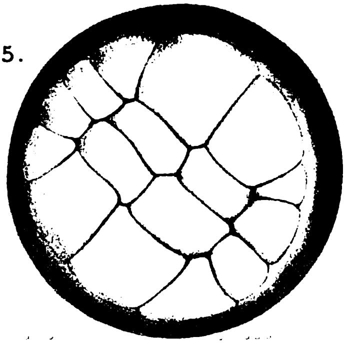

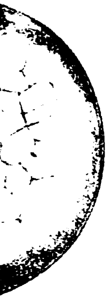

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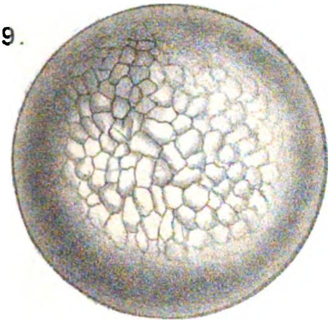

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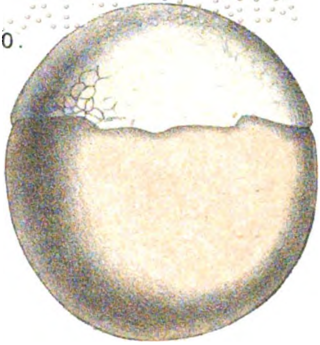

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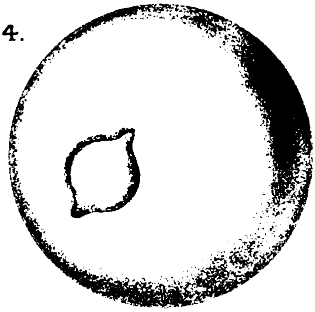

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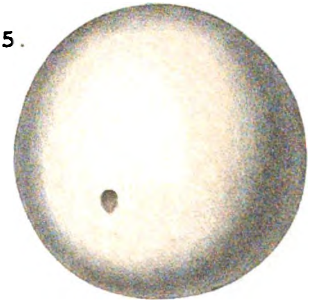

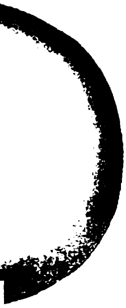

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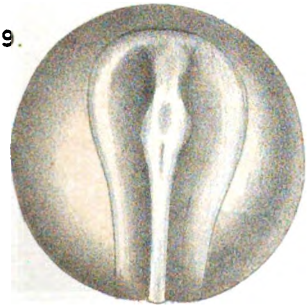

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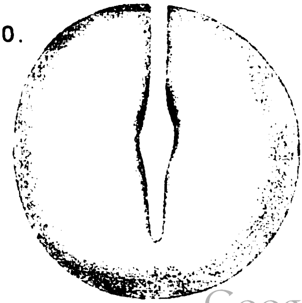

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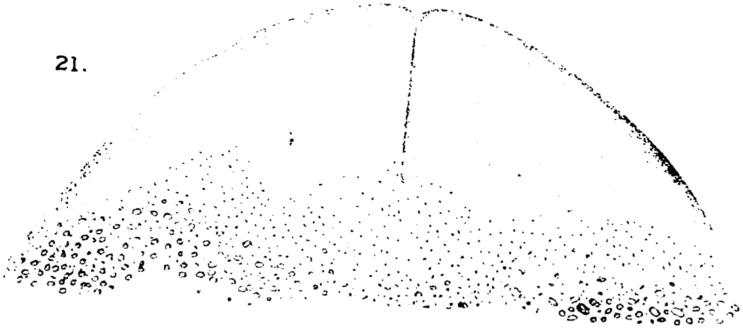

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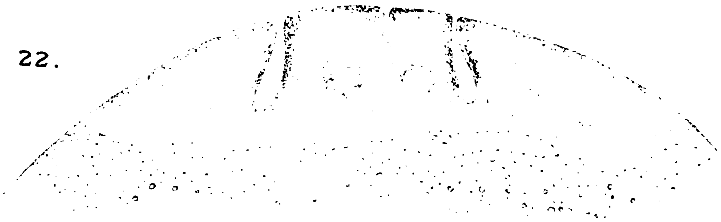

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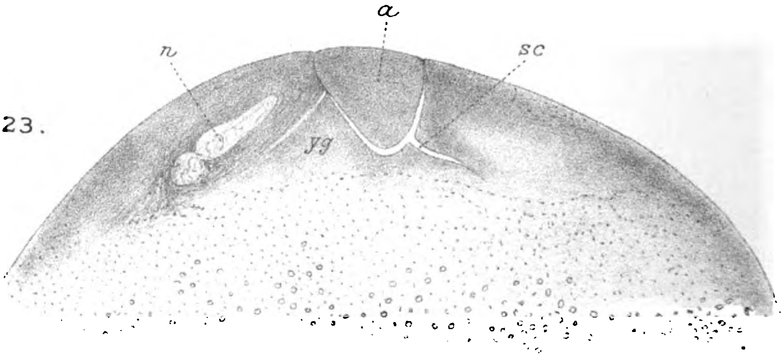

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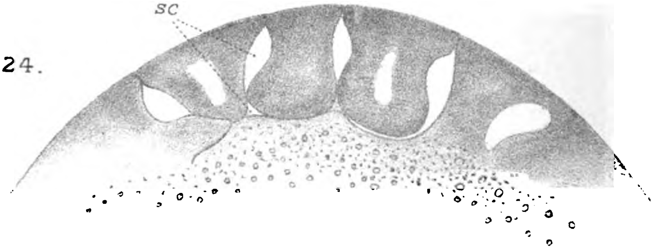

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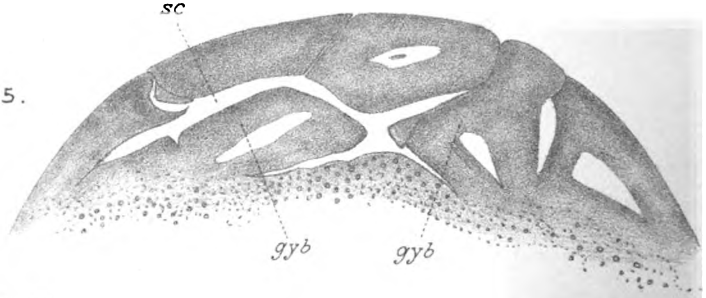

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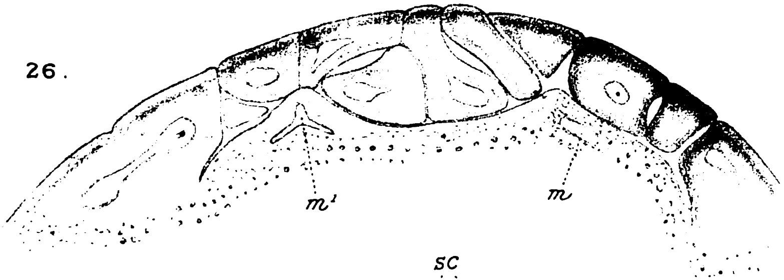

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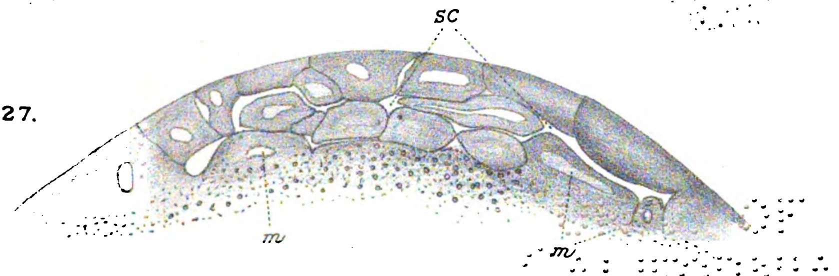

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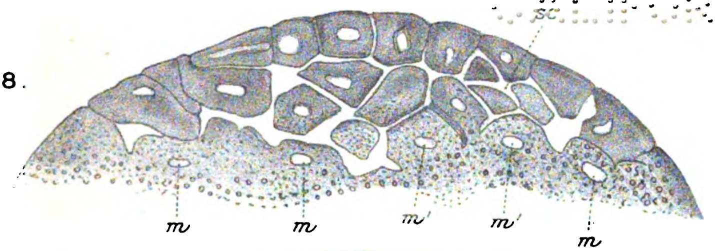

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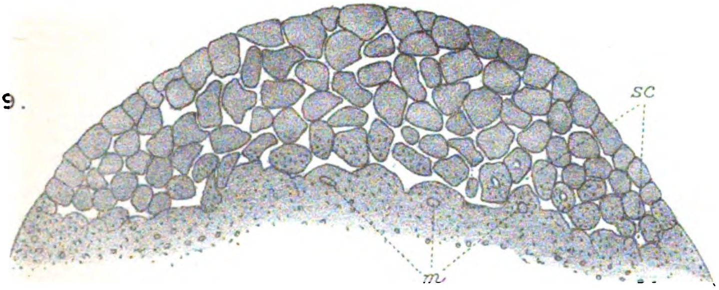

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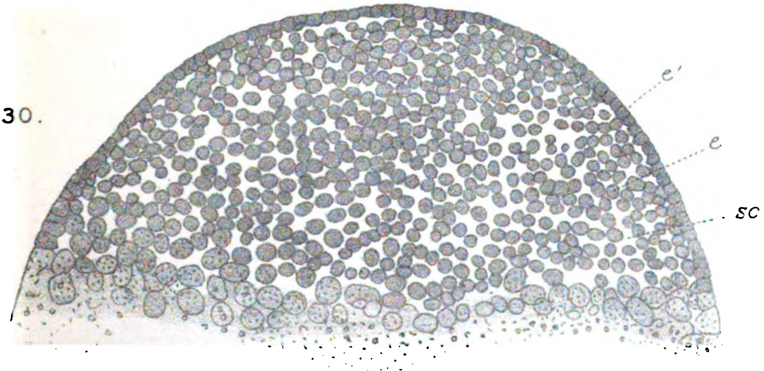

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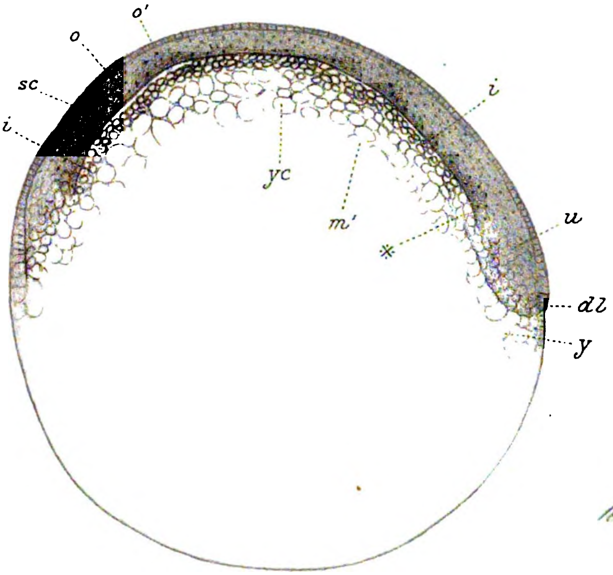

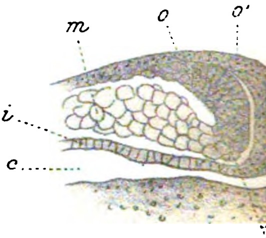

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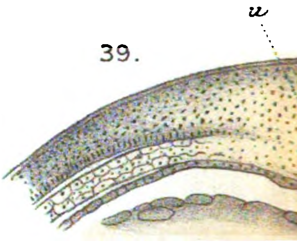

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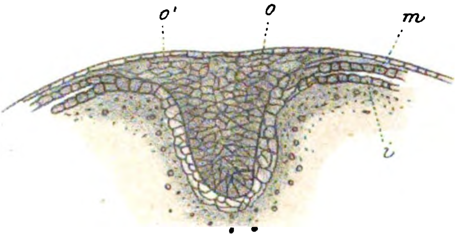

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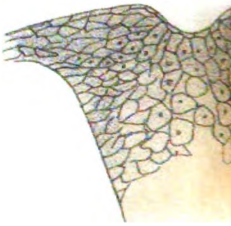

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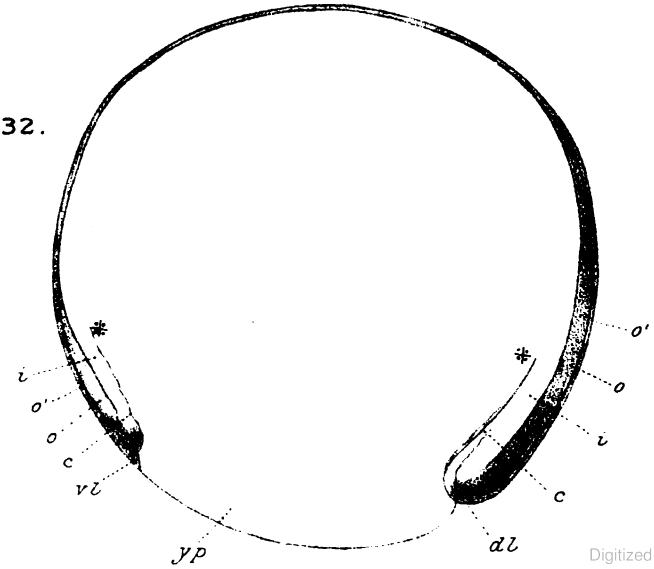

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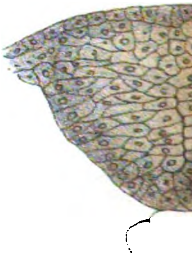

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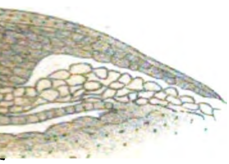

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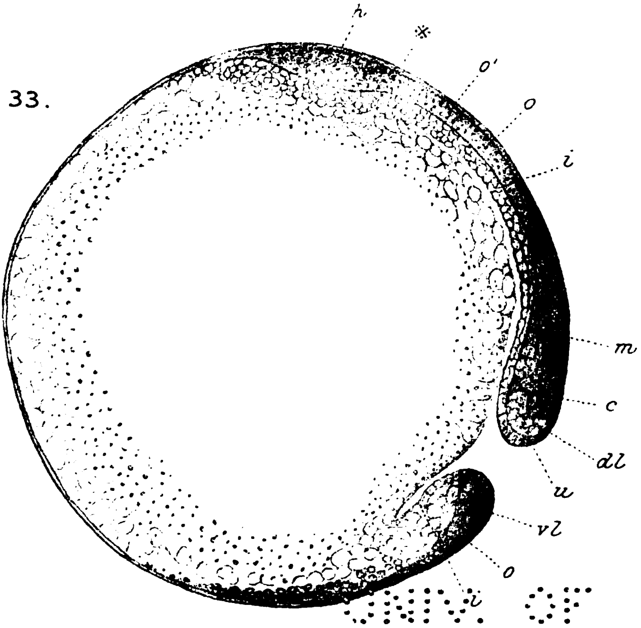

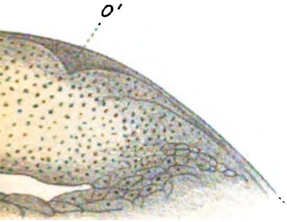

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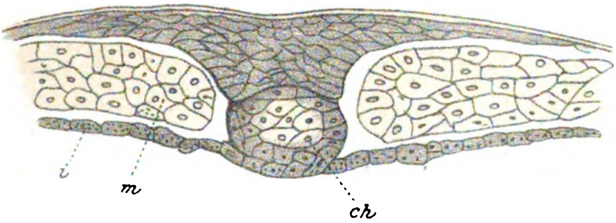

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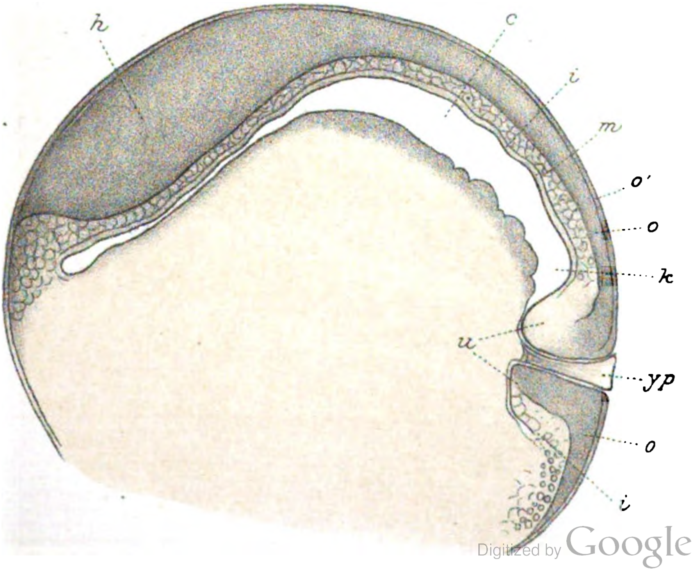

F. Huth, Lith^r. Edin^r.

[*From The American Geologist, Vol. XXXIV, July, 1904.*]

IN THE MATTER OF THE PERMIAN FISH MENASPIS.

By Bashford Dean, New York.

PLATE II.

Among fossil fishes Menaspis has been the source of considerable discussion. For, while it belongs, generally speaking, within the interesting circle of the more ancient sharks, it shows structures which are so puzzling one does not wonder that very discordant views have been held regarding its position in the system of fishes.

Thus, Ewald early maintained that it was akin to Cephalaspis. Jaekel, on the other hand, contended that it represented a "Trachyacanthid," that is, a "placoid" connected with Cochliodus, Oracanthus, Sandalodus, Onchus.* Among other experts, A. Smith-Woodward has regarded it as an armored shark of "some unknown group," and Reis has placed it near the xenacanthids, *i.e.*, ichthyotomous sharks, but later emphasized its chimæroid characters. The discussion, however, has subsided during the past decade, and it is only in the light of an undescribed fossil and after a re-examination of the valuable chimæroid material in the British Museum, and in the Palæontological Museum in Jermyn street, that the present writer has been led to reopen the question of its relationships.

Menaspis is remarkable on two main grounds. The head region, Fig. 1A, is surmounted by what appears to be a series of paired spines (some of which are of a kind apparently unknown in any fishlike vertebrate) which pass from the region of the mouth backward on either side in a graded series. Second, the region which has been regarded as the trunk is enclosed in broad, almost plate-like tubercles, of which a posterior pair protrudes backward, Fig. 1A, C^3, suggesting somewhat the posterior rim of the shoulder armoring in an Ostracophore. These features, it may be remarked, are fully taken into account by professor Jaekel in his description (1891) of the important example of the fossil noticed by Giebel and Ewald.

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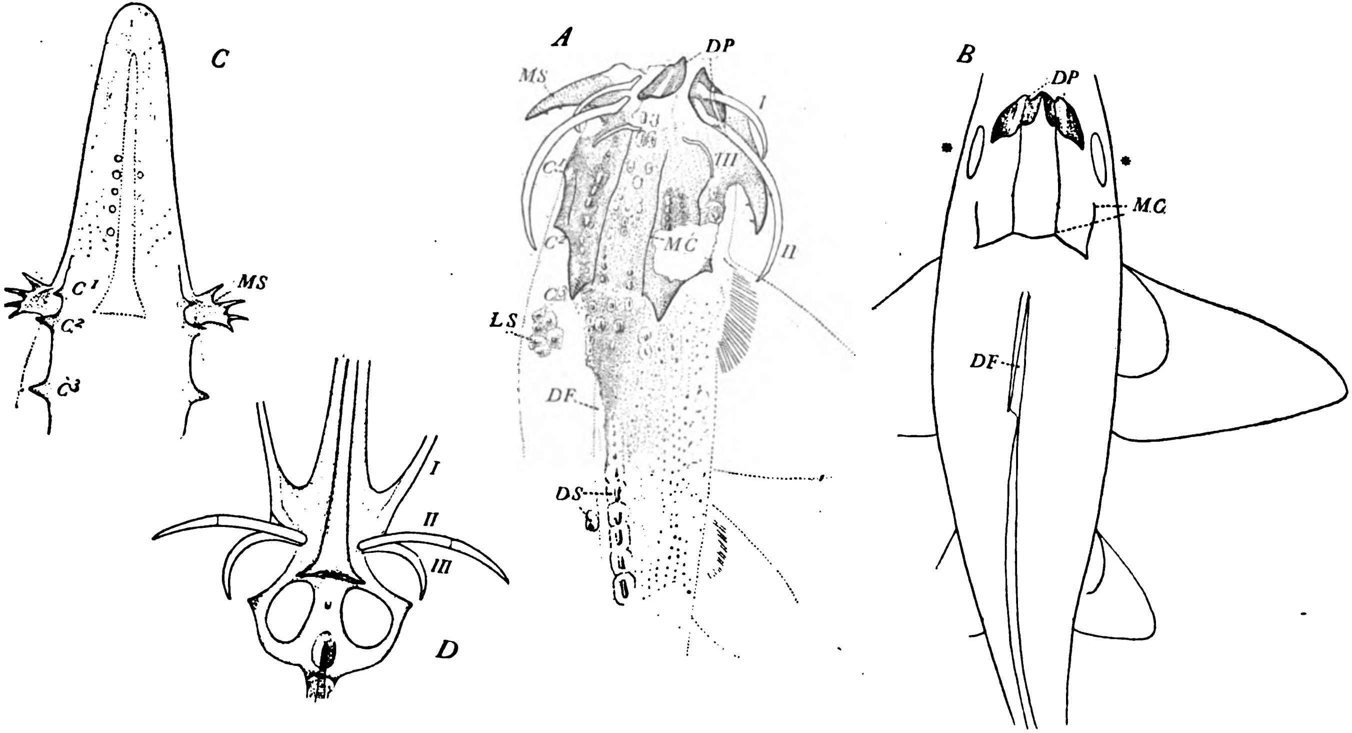
*To Jaekel, in short, it typifies a stage in the phylogeny of fishes where the dentition was plate-like and permanent, and where the dermal armoring was gradually becoming reduced in transition from the plated palæozoic fishes to the shagreen coated sharks. He later ('99) shifts his ground and admits that Trachyacanthids may occupy a position intermediate between sharks and chimæroids.

And it is these features, in fact, that have furnished the basis of later discussion.

One naturally reasons, à priori, that the key of the puzzle of Menaspis will be forthcoming when abundant and better preserved specimens are secured. But this reflection gives little comfort when for a decade no satisfactory material has been brought to light. There is thus, as far as I am aware, but a single additional specimen to be drafted into the discussion. This, it may be mentioned, has been secured by the Prussian palæontological museum. And it is primarily from the examination of this specimen which, thanks to the courtesy of professor Jaekel, the present writer had the privilege of examining during a recent visit to Berlin, that the following notes are suggested.

The undescribed specimen is of especial value since it preserves the dental plates. And from the size of these elements one is *led to conclude that the head could not have been enclosed within the region suggested by earlier authors, and that, accordingly, the posterior spines, hitherto regarded as of the hinder trunk region, mark in reality the region of the occiput.* This view is indicated in the accompanying restoration, Fig. IA, which has been based upon a combination of the contours of the earlier and newer specimens. Confirming this view, moreover, is the presence of the mucous canals already described in Jaekel's (1891) paper. Two of these are present on either side of the head, Fig. 1A, *MC*, one representing the frontal canal, the other the supraorbital. Two additional points strengthen the newer interpretation, first, the presence of shagreen tubercles lying at the side of the fossil, as pictured by Jaekel, and second, the position of the bases of the fins, as also given in the cited work. In the first regard, it may be recalled, Jaekel maintained that these shagreen plates are widely displaced, having been crushed into a lateral position during the process of fossilization: according to the present interpretation, these plates, Fig. 1A, *L S*, remain in approximately their normal position, as the only remnants—somewhat denuded, but corresponding in arrangement with those on the opposite side of the body—of the armoring of the trunk preserved on this side of the fish. In the second regard, it will be seen that the pectoral fin is in its usual position with respect



PERMIAN FISH, MENASPIS.

to the head.* According to Jaekel's interpretation, on the other hand, a large gap must have existed between the head and the pectoral region, and consequently, there was present, or might have been present, a greater number of gills in this form. One observes, furthermore, that in the present rendering the ventral fin occurs in the position in which it usually occurs in shark-shaped fishes. In Jaekel's interpretation, on the contrary, they must have occupied a position far back on the trunk, in the neighborhood, in fact, of the caudal fin.† Jaekel infers that a dorsal fin could hardly have been present in Menaspis. If, however, the present explanation is just, a dorsal fin may well have existed, although it has not been preserved in the type fossil. Its position is suggested by a dotted line in the restoration, *DF*, and the line of shagreen denticles shown in the fossil may have passed beside it, as in the case of chimæroids, both living and fossil.

The dental plates shown in the Berlin specimen, together with the entire fossil, will, it is to be hoped, be shortly figured by professor Jaekel, so that their more definite relations (*e.g.* to Deltodus and similar forms) may be accurately determined. I may, however, be permitted to note that they are strikingly chimæroid in character, reminding one of Rhynchodus, although showing no conspicuous tritoral areas. In any event, the number of these plates is but four, as in the Devonian chimaeroid.

Menaspis and its Relation to Chimaeroid Fishes.

If Menaspis, a Permian form, be closely related to chimæroids, it possesses the interest of being the earliest representative of this ancient group whose body structures are preserved. And that it is essentially chimæroid is shown from the following grounds:

(1) Resemblance to Myriacanthids.—These Mesozoic chimæroids possess a series of lateral head spines which agree essentially with those indicated by *M.S.*, *C* C^2 and C^3, in the present restoration, Fig. 1A. Especially convincing is the similarity of the anterior lateral spines in myriacanthids and Menaspis. In the later form, however, the extreme rim of the

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* The left pectoral fin in the first specimen appears to have been bent under the body, and has been partly exposed by the breaking away of the upper portion of the fossil, judging from Jaekel's figure.

† He does not explain, however, how this tallies with his view that Menaspis was ray-like in habit.

spine is provided, naturally perhaps, on account of its more recent appearance, with more highly differentiated denticles, *Cf.* Fig. 1C. The lateral head spine of myriacanthid has hitherto been regarded as a "dermal plate"* and its projecting denticles have not been perfectly preserved. The writer is, accordingly, greatly indebted to professor E. T. Newton of the Palæontological Museum in Jermyn street, for the privilege of examining an unfigured specimen of *"Prognathodus guntheri"* (*Myriacanthus paradoxus*), from the classic locality at Lyme Regis, which shows these antero-lateral spines in approximately their natural position. One observes in passing that the spines in this specimen had a well marked basal region ensuring their firm attachment, and we have thus additional evidence for regarding the group of trachyacanthids as an artificial one, Jaekel having maintained that the lateral head spines of Menaspis, which are closely to be compared with the present spine of myriacanthids are practically without basal expansion.

(2) Dentition. The dental plates, as above noted, are four in number, and agree essentially with those of Rhynchodus. One notes, in this regard, the peculiar ridge passing along the buccal face of the plate, which finds its apparent homologue in many chimæroids. How closely its tritoral elements correspond remains to be determined by histological study. Moreover, as here denoted, the plates agree with those of chimæroids in their proportion to the size of the head.

(3) Dermal scutes.—These agree in essential characters with those of Mesozoic chimæroids, notably Squaloraja.

(4) Relations of the mucous canals.—These are denoted in the restoration and will be found to agree essentially with those of chimæroid. (*Cf.* Fig. 1B.) They are, moreover, open canals as in recent chimæroids.

(5) Characters of the paired fins.—The basal elements resemble strikingly those of Squaloraja.

(6) Disposition of the so-called paired head spines denoted by I, II and III in the restoration, Fig. 1A.—These structures, shown by Reis to be fibro-cartilage rather than vaso-dentine, apparently correspond to the so-called lip cartilages of Squaloraja. They are, it is true, unjointed, but from

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*Both Woodward and Jaekel have indicated that these spines may have had their position on the sides of the head, Oracanthus-like.

their rounded bases, as is well shown in the type specimen, they were evidently movable. In point of size, moreover, they best correspond to the elements referred to in Squaloraja. Such structures would, moreover, be apt to take a position dorsal to the antero-ventro-lateral head spines during the process of fossilization.

The above considerations lead us, accordingly, to infer that Menaspis, although showing a number of shark-like features, was an early chimæroid. Its likeness to chimæroid rather than to shark is shown notably in the dentition, in the character and disposition of the lateral head spines, and in the remarkable paired "spines" which may be compared to the "labial" structures of Squalorajid. Conclusive proof of its chimæroid affinities, however, will be lacking until it can be shown that the erectile frontal spine was present in the male (the type specimen may have been a female), and that it possessed a dorsal fin-spine and the peculiar vertebral-column known to have been possessed by chimæroids from mesozoic times. The evidence for the present interpretation of Menaspis is at least adequate, I conclude, to enable us to interpret the most troublesome features of the fossil. It is no longer a nebulous "trachyacanthid" with vague affinities to doubtful early groups, but instead, a form well proportioned, (*Cf.* Figs. 1A and B), after the fashion of shark or chimæroid, but with its major features allying it with the latter group. It is remarkable in the possession of well-marked lateral head spines, and in a series of three pairs of greatly elongated and curiously unsegmented spine-shaped cartilages. In the former regard, agreeing with older chimæroids, it presents more specialized dermal developments than are known to have been developed in the contemporary sharks. In the latter regard it is certainly extraordinary, although, as above noted, somewhat similar structures exist in Squaloraja. In short, we reasonably conclude that in Menaspis there is preserved a Permian chimæroid representing a distinct family (Menaspidæ A. S. W.) provisionally to be placed near the Myriacanthidæ and Squalorajidæ. The larger question of the relationships of the chimæroids need hardly enter into the present discussion. It may be enough to indicate that in the matters of dermal defenses and teeth the Permian chimæroids resemble the contemporary cestraciont sharks.

Extrait des *Comptes rendus des séances de la Société de Biologie.*
(Séance du 2 Juillet 1904. — T. LVII, p. 14.)

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L'ŒUF DE CHIMÆRA COLLIEI ET L'ADAPTATION DE SA CAPSULE,

Note de M. BASHFORD DEAN.

La capsule enveloppant l'œuf de *Chimæra colliei*, Poisson Elasmobranche de l'ordre des Holocéphales, habitant les côtes de Californie, est très intéressante au point de vue des facteurs ou des processus de l'Évolution, parce qu'elle montre, mieux peut-être que dans le cas des œufs des autres Vertébrés ou même des Invertébrés, une adaptation frappante à la forme et aux besoins du jeune Poisson, au moment de son éclosion.

L'œuf lui-même, constitué, comme l'œuf d'Oiseau, d'un abondant vitellus, est arrondi, aplati et mou et garde cette forme si on l'extrait de la capsule où il est comprimé. La capsule, au contraire, est comme le moule du jeune Poisson. Elle présente une partie postérieure correspondant à la queue, une partie plus renflée correspondant au tronc et une partie antérieure disposée de façon à permettre l'ouverture et la fermeture de la bouche du jeune Poisson quand il respire. Tout cela est différencié avant que l'embryon ait commencé à se développer : toutefois la capsule subit encore des modifications pendant les quelques mois que dure ce développement; il se forme peu à peu, de chaque côté, une série d'ouvertures, par où entre et sort l'eau, quand le jeune Poisson commence à respirer. En même temps, la consistance de la capsule change. Elle devient dure et élastique et acquiert une tension élastique comme les parois de certains fruits chez les Phanérogames; quand elle s'est ouverte pour laisser échapper la jeune Chimère, on ne peut plus fermer la fente qui s'est produite.

Comment l'Evolution a-t-elle réalisé cette merveilleuse adaptation? Peut-on invoquer le facteur lamarckien, l'usage ou le non usage? Il semble difficile de l'admettre; car, au stade où le Poisson est assez développé pour avoir la forme de la capsule, celle-ci n'a plus d'utilité véritable et par conséquent ce n'est pas un usage fonctionnel qui a pu en déterminer la formation.

Si l'on cherche l'explication par la théorie darwinienne, il y a des difficultés de même ordre. On constate, en effet, dans le développement de l'embryon d'une part et de la capsule (qui est une production de l'oviducte) d'autre part, une série de stades parallèles. Il semble bien difficile de comprendre comment, par le processus de la sélection naturelle, les variations, qui se produisent en tous sens et non pas dans des directions déterminées, aboutiraient à ces deux séries parallèles. Par des variations désordonnées, les coïncidences entre les stades A, B, C, D... dans les deux séries, devraient être rares, c'est-à-dire qu'un très grand nombre d'embryons, pour lesquels elles ne se produiraient pas, devraient être éliminés. Or, ce n'est pas le cas; les œufs de cette espèce se développent sans aucune difficulté, mieux même que ceux du Chien de mer.

Nous concluons donc que les caractères adaptatifs de la capsule de l'œuf de *Chimæra colliei* paraissent être un exemple d'évolution orthogénétique; ce qui, il faut bien le dire, ne diminue pas la difficulté de l'explication véritable de cette évolution.

Paris. — L. Maretheux, imprimeur, 1, rue Cassette. — 7856.

On the Hair-like Appendages in the Frog, Astylosternus robustus (Blgr.)

By Bashford Dean.

AUTHOR'S EDITION, extracted from BULLETIN

OF THE

American Museum of Natural History,

Vol. XXXI, Art. XXIX, pp. 349–351.

New York, November 30, 1912.

Continued from 3rd page of cover.)

Part II.— The Chuckchee: Religion. By W. Bogoras. Pp. 277–536, pll. xxxii–xxxiv, and 101 text figures. 1907. Price, $4.00.

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ETHNOGRAPHICAL ALBUM.

Jesup North Pacific Expedition.

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59.78A:14.78,1

Article XXIX.— ON THE HAIR-LIKE APPENDAGES IN THE FROG, *ASTYLOSTERNUS ROBUSTUS* (BLGR.).

By Bashford Dean.

The presence of hair-like appendages in a batrachian, first noted by Boulenger in 1900, is in itself so extraordinary a morphological fact, that we cannot wonder that it has already been commented upon by several observers,— especially as to the probable function of these organs. Thus Doctor Hans Gadow ('00) points out that the appendages could hardly have been sensory in function, for he found no nerve terminals in them: he noted, however, that they contain lymph spaces and insignificant blood vessels. He later states (1901) that they were studied by Mr. F. F. Laidlow, tells us that "their most remarkable feature is the presence in them of a great number of ordinary flask-shaped cutaneous glands, while such glands are scarce on the surrounding skin," and he repeats his statement that the hairs are lacking in sensory structures. Mr. Boulenger in a second paper ('02) makes it clear that the "hairs" occur only in the male, but he gives us no clue as to their significance. And very recently (Feb. 1912) Dr. Kükenthal, examining the specimens in the Museum of Comparative Zoölogy of Cambridge, Mass., states that the hairs are to be regarded as highly developed tubercles of the skin and he interpreted them "as secondary sexual organs, charged with sensory functions." He comments upon their appearance "only on those areas of the surface where, according to Merkel, in other frogs these tactile cells ('Tastflecken') form aggregations." Kükenthal gives in his paper a transverse section of one of the "hairs" in which appear blood-vessel, cutis and epidermis, and he figures also a portion of a longitudinal (radial) section in one of the cutis ridges: in this are seen chromatophore, nerve fiber, and "tactile cells." The last, we infer from his text, were noted only after impregnation of the tissue by Bielschowsky's method.

The American Museum has recently received from Doctor Thomas Barbour, in an exchange with the Museum of Comparative Zoölogy of Cambridge, one of the specimens of *Astylosternus*, which Kükenthal examined; and the study of the disposition of the "hairs" and of their structure has led to recording the present notes:

First of all, assuming that these "hairs" are developed by the male and only at spawning time, and that they attain, as Kükenthal's figure shows, great length in certain specimens, one is led to correlate this with a habit of brooding not uncommon among amphibians generally. It is known, for example, that in various salamanders,— *Cryptobranchus, Amphiuma,*— in *Ichthyophis, Alytes,* in various Hylids and in *Rhacophorus reticulatus,* the eggs when extruded are wrapped about or attached to the body, in each species in one sex only, usually the male. In the case of the present frog, therefore, it is but necessary to compare the condition with that of such a form as *Alytes* (*cf.* Figs. 1 and 2) in which it is known that egg-strings are attached to the sides of the body and the thighs, to obtain more than a suggestion as to the function of these hair-like processes, *i. e.*, that they were used for retaining the egg-strings in such position that they could be readily transported, guarded, and probably oxygenation as well. It will be recalled in this connection that the lungfish, *Lepidosiren paradoxa,* which has also the brooding habit, develops on its ventral appendages hair-like processes which are suffused with capillaries, and admirably adapted to bring oxygenated blood in close contact with the mass of eggs. In this instance we can safely conclude that the hair-like processes function as an accessory respiratory organ for the developing young.

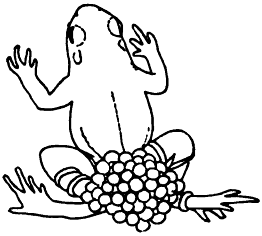

Fig. 1.

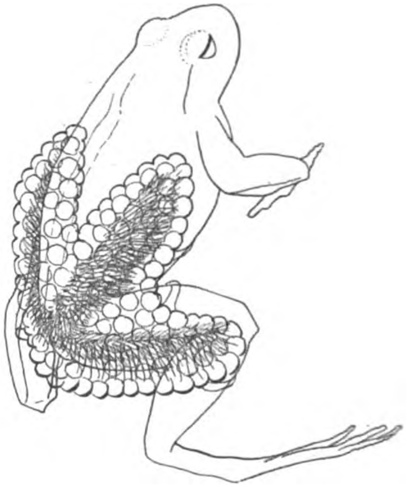

Fig. 2.

In fact the histological notes which Kükenthal has given are not opposed to the present view. Each hair is vascular: its core of cutis is made up of spongy tissue; furthermore, from the arrangement of the surrounding epidermis in curious ridges, we suggest that the circumference of the hair could have been notably dilated; we note also that pigmentation is largely abandoned and that the number of delicate nerves with terminal cells, which

Kükenthal has described, would be no more than one would expect in a specialized structure of this kind,—for after all, the appendages are dermal and secretory and as such would be apt to be provided with nerves and sensory elements.[1] If, however, their function were exclusively or even largely sensory, as Kükenthal maintains, we would reasonably —by numerous analogies in the appendages of amphibia and fishes,— expect that the sensory organs should be far more conspicuous. Then too, if the former view is to be accepted, one would expect to find among amphibia sensory structures developed seasonably. But this is a condition which apparently does not occur.

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[1] My sections show that nerve endings are demonstrated only with difficulty — as one would expect in the case of nerve terminals in cutaneous glands.

W D Matthew

18

THE PRESERVATION OF MUSCLE-FIBRES IN SHARKS OF THE CLEVELAND SHALE.

BY BASHFORD DEAN, COLUMBIA UNIVERSITY, NEW YORK.

From the American Geologist, November, 1902.

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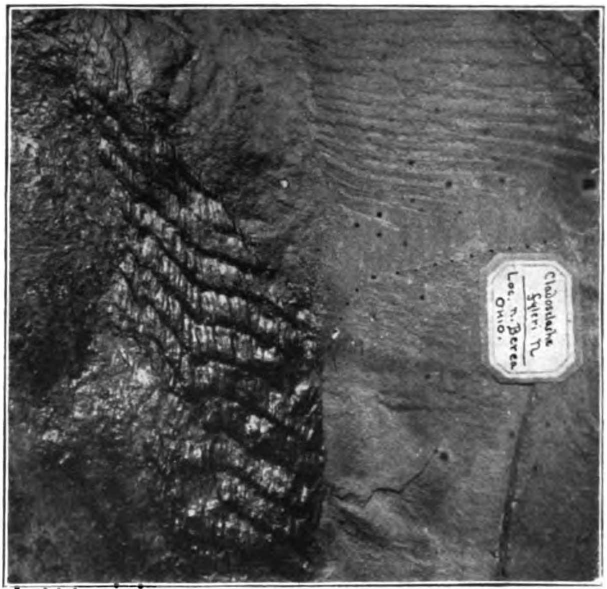

Fig. 1. Cladoselache fyleri, showing fossilized muscle bands. The margin of the trunk passes vertically through the middle of the figure; part of a pectoral fin appears at the right, its hinder rim made more prominent by a row of black dots. Nearly natural size.

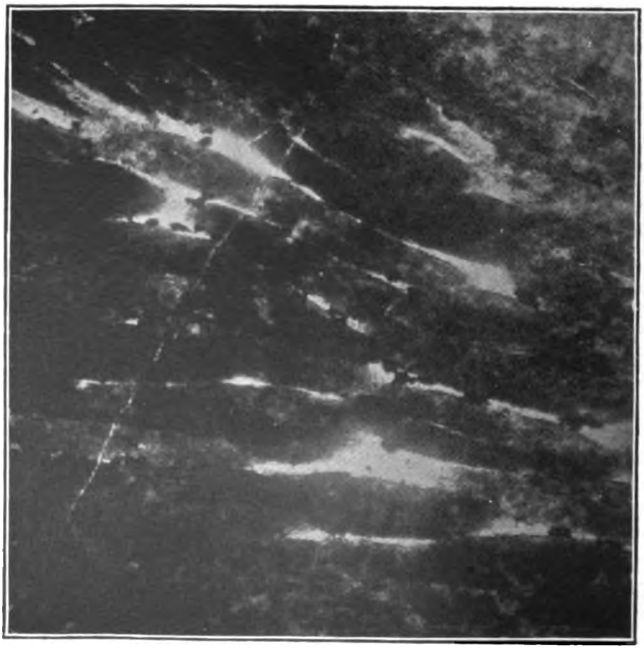

Fig. 2. Cladoselache fyleri. Section of muscle band photographed under a low power, showing outlines of fibres.

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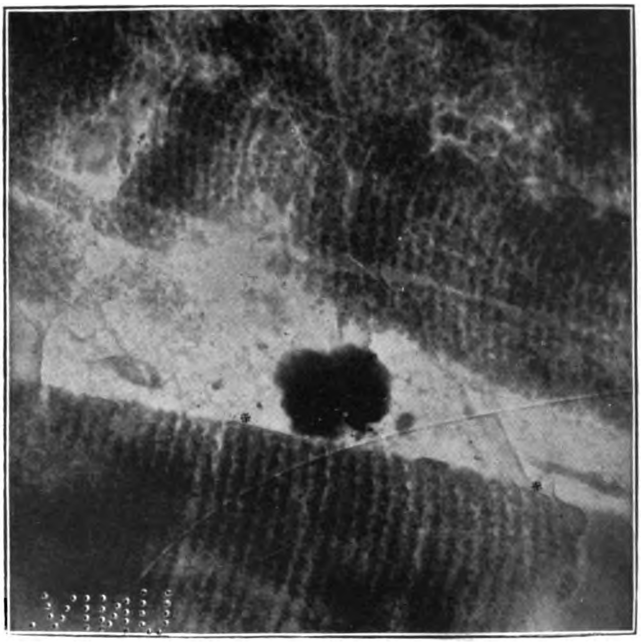

Fig. 3. Cladoselache fyleri. Muscle fibre detail, showing transverse striature. x about 1000.

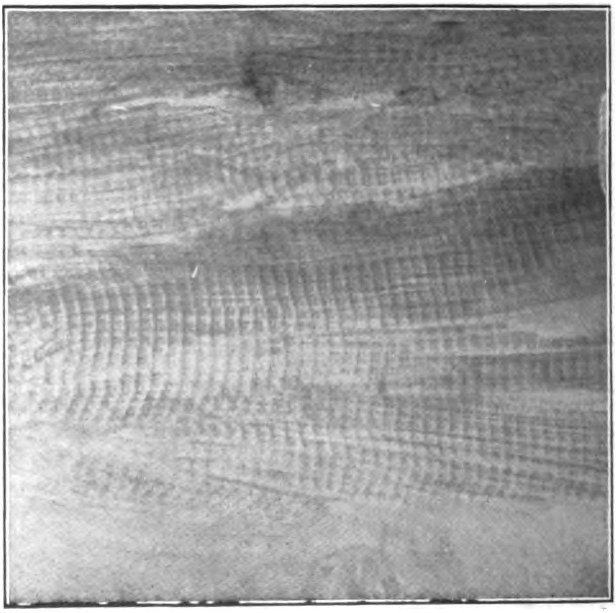

Fig. 4. Heterodontus japonicus. Muscle fibre detail, showing transverse striature. x about 1000.

[*From the American Geologist, Vol. XXX, November, 1902.*]

THE PRESERVATION OF MUSCLE-FIBRES IN SHARKS OF THE CLEVELAND SHALE.

By BASHFORD DEAN, Columbia University, New York.

PLATES VIII AND IX.

In fossils of vertebrates, fragmentary as they are, soft parts are sometimes preserved with startling clearness. Muscles and integumental webs are well known in a number of groups, and the student of palæanatomy has even collected convincing data regarding the nature of such frail organs as soft-walled viscera and spinal cord. Muscles, especially, are apt to be well preserved, even to the details of their individual fibres.

Favorable instances of the fossilization of muscle fibres are by no means uncommon in the fishes of the lithographic stone, as Reis has pointed out. Here in the case of the ganoid *Undina*,* he has described the fibres and their "reizende Striation," as so well preserved as to give an "ideale Bild der Muskelstructur,"—although this optimistic conclusion may not be shared by a reader on account of Reis's indifferent figures. And even in less finely grained sedimentary rocks examples are not lacking, both here and abroad, of well preserved soft tissues. In the case of an American matrix the Cleveland shale deserves especial mention, since it will no doubt provide many important facts regarding the intimate characters of the Devonian vertebrates. The reader may recall, for example, that it was in this shale that Newberry† first suggested the preservation of trans-

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*Die Coelacanthinen, m. bes. Berücks. d. Gatt. d. weiss. Jura Bayerns. *Palæontographica*. Bd. XXXV, Taf. II.

†Mon. XVI. U. S. Geolog. Surv.

verse muscles in specimens of the remarkable cladodont sharks (*Cladoselache*).

The strikingly preserved tissue in these specimens had long been known to the present writer; but it was only recently, while re-examining the structures of cladoselachids, that he caused favorable fragments of it to be microsectioned. The material was then found so well preserved that he was led to prepare the following notes upon it, illustrated by photomicrographs. The latter were taken by his colleague, Dr. Edward Leaming, to whose generous aid,—in this as in similar instances,—the writer is greatly indebted.

It may be said, in passing, that the specimens of Cladoselache referred to by Newberry are of exceptional value to one who is studying fossilization as well as palæanatomy; thus in the type of *C. kepleri*, gill filaments are reproduced distinctly; and in several specimens the mineralized muscle bands, sometimes in patches several inches in length, are so well preserved that they suggest in color, distinctness and texture, the mummified tissue of recent fish. Pl. VIII. Fig. 1.*

The general appearance of the fossil muscle fibres is well shown in Pl. VIII, Fig. 2, from a photograph taken under a low power. One notes the crowded mass of cylindrical fibres whose outlines, in many cases clean-cut, suggest that the tissue at the time of its fossilization could not have been badly decomposed. Indeed, judging from Pl. IX, Fig. 3, in which a similar section is magnified about 1,000 diameters, one can conclude that the tissue was even in a very fair state of preservation, for, considering especially the fact that the fibres have undergone mineralization, the striae are still undistorted, and even what can reasonably be interpreted as bits of the sarcolemma (at the point * and *) are reproduced. These ancient muscle fibres, in fact, preserve the contours better, as it happens, than the fibres in recent tissue in the adjacent photograph, Pl. IX, Fig. 4, taken from a well preserved specimen of *Heterodontus*.

Comparing further the preparations (both magnified equally) of the Devonian and of the recent shark, we cannot fail to note the greater coarseness of the transverse striae in the ancient form. Here, in general, the striae are one-third, or thereabouts, less numerous. And I am accordingly inclined to believe, even taking into account the possibilities of the relaxed condition of the fibres, and of artifacts due to fossilization, that the ancient shark had not yet attained the high degree of muscular specialization of its modern kindred. This conclusion is materially strengthened by our knowledge of other primitive characters of cladodonts. (For summary v. *Natural Science,* 1896, vol. viii, pp. 247-253.)

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*In the present figure (from a specimen of C. fyleri) there is shown also a portion of the characteristic Cladoselachian (pectoral) fin. Its web can be traced back along the side of the trunk in the line indicated by dots.

Regarding now the process of the mineralization of such delicate structures as muscle fibres, interesting in a somewhat wider aspect paleontologically, Reis has written in considerable detail.* He finds that in lithographic stone fossils (and this will hold in a general way—*t.* Lankester and others—in the case of similar fossils from other rocks) the muscular mass is purely mineral, composed largely (80%) of calcium phosphate. On various grounds he concludes that the muscular tissue could have been but in a semi-decomposed condition (halbfaulen Zustand), that mineralization took place relatively quickly, and that the object must have been so completely and thickly enclosed as to prevent further disintegration. Unlike Owen, Reis maintains,—in this point, justly, it seems to me,—that the fossilization could not have been a part of or a sequel to a process of adipocere-making. He further concludes that the phosphate is derived from the body itself, product mainly of muscles and blood, precipitated when the decomposing material is brought in contact with the lime carbonate of the sediment of the sea bottom. As the petrified muscle has more phosphate in it than the recent tissue it follows, he maintains, that it has received the phosphate from the remaining muscles, and these, therefore, have not been preserved. In any event, final decomposition of such an organism takes place much more slowly in the deep sea than one is apt to believe, and there is thus a better chance for the gradual mineralization of tissues *i. e.,* by precipitation of lime.

The foregoing explanation covers the matter of delicate fossilization ingeniously, and in some ways satisfactorily. But in other regards it is, I think, open to serious objections. For,

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*89 Ueber eine Art Fossilisation der Musculatur. *SB. Gesell. Morph. München*, pp. 6.

in the first place, it presupposes a sufficient decomposition of the tissue to warrant its giving up its phosphate component, a chemical condition which, it seems to me, predicates a breaking down of the fibres, certainly to the degree of their losing their delicate striation. And we know, on the contrary, that the fibre structures were not decomposed, for they are reproduced in an amazingly perfect way. Nor can we, I believe, assume that, *if precipitated* from neighboring decomposed tissue the lime phosphate will be transferred bodily into the fresher fibres in so perfect a way as to preserve their minute details. On the other hand I cannot feel that it is necessary to assume that *all* of the lime phosphate was derived from the animal fossilized as a product of its decomposition, or that even a goodly part of the phosphate was thus deposited; it is a simpler interpretation that it came in solution from foreign sources. For in this way we can best understand how a tissue in a fairly fresh condition can be mineralized, the fibres themselves absorbing the dissolved phosphate in their neighborhood, accumulating it very much as fluorides are taken up by fossil bones, or as lime carbonate is accumulated by bone when placed in running water, conditions to which Reis himself refers. Moreover, from what we know of the formation of phosphates, *i. e.,* in the river mouths of South Carolina, we have reason to believe that this material is peculiarly apt to accumulate, and that with this process is a phosphatizing of organic remains. Thus an object which has normally but a small amount of phosphate becomes transformed, often with great histological delicacy, into a fossil made up largely (over 90%) of calcium phosphate. This instance, however, is an extreme one, dealing, as it does, with a mineralizing process which extends over kilometers of river bottom; simpler is the case of the present sharks in as much as the phosphatizing of tissue occurred in a tract whose area measures but a few centimeters, and whose thickness is less than a millemeter. Moreover, from the quantity of the fossil tissue preserved, we know that it is in nearly every case but a scale-like portion, or, better, a delicate crust of the body wall which has been preserved, a feature which tells, I think, in favor of the present interpretation. In this regard it follows also that the fresher the tissue to be fossilized, the better are its chances for accumulating phosphate; for it remains for a longer time passive and the osmotic changes can better be felt in even its minutest texture. During decomposition, on the other hand, the petrifying tissue would have broken down, first in its cytoplasmic structures, later in its membranes, through processes whose energetic operation could hardly have been favorable for the depositing of accurate casts, or for the action of continuous and unaltered osmosis. In the present specimens one also notes that the phosphatizing of the muscles occurs only at favorable points of the fish's body and only on one side of the body, judging in the latter regard from sections. This fossilized region I am led to identify as that portion of the animal which was in closest contact with the phosphatizing sediment. For if a solution containing such a sediment be prepared artificially and recent tissue introduced, the latter is found to lie on the surface of the sediment, and, decomposing, leave a crust where its mass has been in closest contact.

As far as Reis's further conclusions go, one can, I think, safely agree with him regarding the matter of slowness of decomposition under conditions of marine deposits, *fide*, recently,the results of the Siboga expedition; indeed, even in shallow water, recalling Moseley's experiments, disintegration may take place slowly enough to enable a delicate object to become saturated with phosphate if placed under suitable conditions, a circumstance to be borne in mind in the case of the Cleveland shale, which is probably not a deep water deposit. We can also reasonably conclude with Reis that the muscular tissue mineralized relatively quickly.

The foregoing considerations, it seems to me, add an item or two to our knowledge of the primitive status of the Cleveland shale. From evidence contributed by Newberry and others it has been regarded as an estuary deposit; add to this now a condition which caused its vertebrate remains to become delicately phosphatized, and we picture it as a sediment similar to that which was deposited in the early tertiary in the river-fed estuaries of South Carolina. If again, the phosphatizing of the muscular tissue took place at or near the surface of the bottom-sediment, as I think there is good reason to conclude, we have an interesting note as to the consistency of the sediment, for it was then soft enough to enable a fish of smallish size, say of a foot or two in length, to sink into it naturally until partly or completely submerged. I say, sink into it naturally, for it is a well known fact that these sharks are in every case * preserved in the same position, ventro-dorsal, having sunken to the bottom doubtless with belly upward, still partly distended with gases. The bottom-sediment, accordingly, was soft and fine. It was also probably deep, since in some cases the sharks have sunken into it completely, the well preserved fins passing out of the general plane of the fossil into an overlying portion of the matrix. Moreover the sediment could have been subject to no extensive movements, since these sharks, although collected over a wide area, show no evidence of having changed position (*i. e.*, rolled) from the time they first sank to the bottom.

Surface currents, on the contrary, may well have been present, since in the shale the remains of fishes with swim-bladders are conspicuously rare, in spite of strong evidence for believing that they must have been plentiful at that time, and even in that region (judging, *e. g.*, from the abundance of sharks and from their stomach contents). And we can best interpret their rarity in fossils as due to the presence of surface currents; for such types of fishes, unlike sharks,† would float during earlier stages of decomposition, and thus, on the assumption that currents were present, would be carried either ashore or to sea, in either case escaping fossilization.

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*A single instance should be excepted in which a fish, fossilized in the usual position, shows the caudal fin turned on its side.

†If this evidence be admitted the curious coccostean "fishes" of the Cleveland shale are also to be interpreted as lacking a swim-bladder. There is, I believe, but little ground for associating them with ganoids and lung fishes.

[illegible]

Bashford [illegible]

ADVANCE PRINT FROM THE PROCEEDINGS OF

The Seventh International Zoölogical Congreſs

Boston Meeting, August 19-24, 1907

19

THE PLAN OF DEVELOPMENTS IN SERIES OF FORMS OF KNOWN DESCENT AND ITS BEARING UPON THE DOCTRINE OF PREFORMATION

BASHFORD DEAN

CAMBRIDGE, MASSACHUSETTS
1909

THE PLAN OF DEVELOPMENT IN SERIES OF FORMS OF KNOWN DESCENT AND ITS BEARING UPON THE DOCTRINE OF PREFORMATION

BASHFORD DEAN

ONE of the greater problems of the embryologist is to determine whether the embryo is "preformed" in the egg, or whether it arises through a series of epigenetic stages, which in their sequence recast or repeat the organism's ancestral history. We know, of course, that in the case of some animals the embryo is "preformed" (*i. e.*, prelocalized), to a startling degree, at the earliest cleavage, or even before it. We know with similar definiteness that in other forms the embryo develops epigenetically, one embryonic stage supplanting another, and that the component elements transform from step to step, undergoing changes both in quantity and in quality. And we know that various embryologists have tried to explain these opposite types of development in various ways. Extreme mosaic types, to quote Whitman, — and I infer that this is his own view, — "are commonly supposed to reflect *precociously* the later organization," that is, the mosaic type of development is to be looked upon as an abbreviated form of an epigenetic development. Other writers (*e. g.*, Fischel) regard the two types of development as essentially unrelated to one another; while others still, Huxley and his followers, are inclined to believe that epigenesis is in essence a slowly developing form of evolution (preformation). As far as I am aware, however, no attempt has been made to consider the question more closely from the point of view of phylogeny (*i. e.*, by analysing series of forms of *known* descent), — a most profitable mode of attack, it seems to me, since we admit that the present developmental processes have come into being as modifications of the developmental processes of ancestors.

It is in this regard that I wish to call attention to the value of vertebrate[1] embryology, since in the vertebrates, thanks to palæontology, we have a clear demonstration of the descent lines of a number of the component groups. Accordingly, if we can demonstrate that the forms *C*, *B*, *A*, represent a phyletic series, we conclude that the embryonic processes of the forms of the group *C* are derived from those of *B*, and these in turn from *A*. Furthermore, the fact that the groups are derived from one another in relatively recent times precludes the probability of the appearance of a confusing range of adaptive changes. Thus, then, we may be assured of a favorable means of identifying, classifying and comparing embryonic processes, and of determining to what degree specialized (localized) stages may appear in the embryos of various groups.

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[1] The invertebrates, on the other hand, contribute but scanty tangible evidence for the solution of this problem. For little is known of their palæontological origin. And their groups, even to many of the ordinal and subordinal divisions, have been separated from each other for such great intervals of time that we may, in our present knowledge, readily conclude that the intergrading ontogenetic processes have become lost. We may understand also, in view of such lapses of time, that numerous adaptive changes have come into being, affecting all stages, sometimes producing complicated parallelisms, *e. g.*, in lawful stages, or local differences.

The results of such a study, carried out from the point of view of the phyletic derivation of the embryonic changes, throw light, I believe, upon the problem of localization, for by this means we may show that various structures become developed precociously in embryos of groups of later derivation. That is, that the later groups may produce embryos of a mosaic type. And by such series we may demonstrate that certain mosaic embryos are to be interpreted not as primitive or as independently developed forms, but as precociously segregated derivatives of epigenetic ancestors. That, however, *all* mosaic embryos are to be interpreted in this fashion does not strictly follow from our present premises; but we cannot deny that the evidence of serial forms is to be given the greatest weight.

Series of forms of known derivation are, *e. g.*:

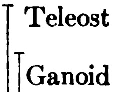
Birds < Reptiles
Teleosts < Ganoids
Chimæroids < Sharks
Amphibians < primitive Lung-fishes (essentially Crossopterygian).

We may note that in any of these series the *plan of development* is found to undergo a marked improvement in the later members of the series, — "improvement" in the sense that the young acquire such structural characters that they become more perfectly self-supporting and in a (relatively and often actually) shorter time.

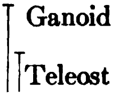
To cite an instance: —

Teleost < Ganoid

The phylogenetic development would be represented by longer and shorter lines, thus: —



But in the actual time[1] of embryonic development, thus: —



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[1] This is true of the majority of Teleosts, — not of those which have evolved peculiar adaptations, *e. g.*, development in icy water, etc.

Now in this state of affairs the greater rapidity of development of the derived type of animal cannot be due *magna parte* to the greater rapidity with which the embryo's cellular divisions are taking place. For it is known that the rate of mitosis is not widely different in these forms.[1]

In short, it can, I believe, be demonstrated that in a derived form, such as a teleost, there are fewer cells present in the embryo than in corresponding stages of the less-modified ganoids. If then the teleost is able to become self-supporting with its fewer cells, we conclude that these cells in the process of their evolution must have acquired greater specification (prelocalization). In such a case, however, the objection might, with Huxley, be raised that what seems a more epigenetic type of development is *in esse* preformational, manifesting itself only at an earlier period. But this objection loses its weight, it seems to me, when one takes into account such series of forms of known descent. For it then becomes clear that the changes in these series which lead to mosaicness are not manifesting themselves from the egg outward, *i. e.*, arising in the earliest stages and becoming evident in a centrifugal fashion, but are gradually evolving in the reverse direction, centripetally, *i. e.*, the structures of late stages are being inherited at a younger period, in the fashion of "acceleration," as long since demonstrated by the palæontologist (*e. g.*, Hyatt). In a word, characters of the late "larva" of the ancestral form come to appear in the early embryos of the derived form: characters of the early "larva" of the ancestral form appear in the gastrulation of the derived form; characters of the late gastrulation of the ancestral forms are "shunted back" into the segmentation stages of the derived form.[2]

In other words, in the derived form the "stages" come obviously to exist upon a scaffolding of fewer subserving cellular elements. A cell in the notochord of a specialized teleost may be equivalent to (about) 6 cells in the corresponding stage of the ganoid, a cell in the spinal cord to (about) 10 cells in the ganoid, a cell in the mesonephros to many mesonephric cells in the ancestral form, a cleavage blastomere, finally, to many cleavage blastomeres. In short, we are dealing in such cases with a centripetally "compressed" development, one which becomes more and more mosaic, in expressing the later stages of the ancestors in the earlier stages of the descendants.

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[1] There is clearly no exact recapitulation of the ancestral stages in the embryos of the derived forms (thus the teleost does not recapitulate the *exact* stages in the ganoid). Yet all will admit that the plan of development of the second form is a modification of the plan of development in the ancestral form.

[2] To cite a few details (taking the teleost as an example):

(1) At about the 5th cleavage in the teleost appears periblast, which is the homologue of (but more perfect indeed than) the subgerminal zone of nuclei at the period of late gastrulation in ganoid.

(2) In late cleavage appear "germ cells" which in the ganoid can be identified only in later embryonic stages.

(3) Before the close of gastrulation the teleost's nervous system extends 250° around the egg, while in sturgeon and garpike it measures scarcely more than 90°.

(4) In early larval stages the teleost attains a homocercal tail, a condition acquired only in more modernized ganoids, and at a late larval period.

In such a case, *e. g.*, teleost, furthermore, we note that the embryonic "improvements" have taken place within measurable time (since the late mesozoic). And if such changes can be produced within a relatively short time we may assume, not unreasonably, that the "shunting back" (acceleration) of useful embryonic structures would become expressed more clearly and in earlier stages if longer time permitted, say twenty, or a thousand, times longer than in the case in point. We therefore conclude that out of the developmental plan of epigenesis may arise the developmental plan of mosaicness, — *ex epigenese præformatio.*

POSTSCRIPTUM. — If we admit the general proposition that preformation may be derived from epigenesis as the result of an accumulated series of changes, concentrated into earlier development in the course of time, the time factor is evidently to be given the closest consideration. And the following inductions are, I believe, tenable: —

I. If two descent lines of animals have been separated from each other for an exceedingly long period, the plan of their development would tend to become specially adapted to each separate group. This result, however, would be less evident in the separate groups should they retain identical living conditions during any or all periods of ontogeny. Thus, if the conditions for the growth of the earlier stages in the two separate lines remained unchanged, these stages would fail to develop unlike adaptations: if in the two separate lines the later stages alone remained under identical living conditions, the most conspicuous changes in plan of development would be in the earlier stages. If the adults alone remained under identical living conditions, the plan of embryonic development would differ in proportion to the length of time available for this adaptive evolution: *i. e.*, in such a case, if the time were of great duration, the adaptive embryonic changes would be striking (*e. g.*, Peripatus).

II. Thus, conversely, should two forms similar in structure be found to differ in their plan of development, we would conclude justly that these forms had been separate for a long period of time (*e. g.*, hagfish and lamprey).

Compliments of

Bashford Dean

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B. DEAN

Some embryological evidence as to the position of Chimæra.

Extrait des Comptes rendus du 6^{me} Congrès intern. de Zoologie.
Session de Berne 1904.

Sorti de presse le 25 mai 1905.

Extrait des Comptes rendus du 6e Congrès international de Zoologie.
Session de Berne 1904.

Some embryological evidence as to the position of Chimæra.

By Dr Bashford DEAN (New-York).

During the past half century various investigators have referred to the Chimaeroid fishes as picturing in many regards the ancestral jaw bearing vertebrate. And in this they have based their induction upon an extensive series of anatomical and palæontological facts. On the other hand, these evidences have been controverted vigorously by the upholders of the view that the ancestor of the ancestral vertebrate could not have been widely different from a modern shark.

Reviewing these evidences, one must, I believe, speedily admit that the palæontological evidence in support of the view that the Chimæroid was the more generalized form is sadly defective, for no definite data dating from periods more remote than the Jurassic is at hand. The jaw plates of Ptyctodontids upon which all rely as exemplifying Devoni n members of this group certainly *appear* Chimæroid, but as we know nothi g else (*e. g., re* body structures) regarding this family, it is hardly possi e to decide whether they were really the ancestral Chimæroids or whether they may not have been equally well aberrant forms of sharks. The so-called tritoral points which are present in these plates resemble closely structures in some of the early Cestraciont sharks.

As to the anatomical evidence, we may note that the peculiar solid (holocephalous) character of the skull was regarded as a secondary condition even in the time of Johannes MÜLLER, and that the majority of the much discussed anatomical features in this curious group are looked upon at the present time either as primitive, or as neotænial, or even as very highly specialized, according to the standpoint of the individual observer.

The embryological evidence upon this problem, however, still remains to be considered, and to this I purpose to refer briefly in the present paper. In this connection it may be recalled by those who are interested in the problem of the relationships of the Vertebrates, that the middle and late stages of the development of the Australian Chimæroid *Callorhynchus,* have been lately described by SCHAUINSLAND, and that the younger stages, of the Californian *Chimæra colliei,* have been referred to briefly (1903) by the present writer. At the present time it may be pointed out that in a number of important regards the development of *Chimæra* indicates a remarkable degree of specialization, and that these conditions can only be interpreted on the ground that the Chimæroid fishes in the course of their evolution have departed developmentally from the simpler features of sharks. In passing, I might refer to the following conditions:

The Chimæroids are highly specialized:

First: In the means fertilizing the eggs: in this regard witness, for example, the erectile frontal and ventro-lateral spines, and the peculiarly modified pterygopods. In the last, as in the genus *Harriotta* or *Rhinochimæra,* the component elements are fused into a single cartilaginous nail-shaped plate.

Second: — In the remarkable egg caspules. These are far more highly specialized than in any known Elasmobranch. They are of gigantic size, measuring without their terminal organ for attachment relatively about one quarter the length of the parent fish: they are, moreover, oriented for the young fish at the time of hatching, having a definite region for its snout, trunk, tail and caudal filament, and even for its dorsal and ventral sides. The capsule is constructed, furthermore, so that a system of breathing pores will weather through the shell at the appropriate time, and that an elaborate operculum will appear at the time of hatching. This capsule altogether affords an interesting case of almost perfect adaptation, one, by the way, whose origin it is difficult to understand on the ground of pure natural selection. For how may two morphologically independent characters (*i. e.,* in the developing embryo and in the capsule secreted by the oviduct) continue to coincide during selection of fortuitous variations in the different stages in development, so that in the end a species might continue to survive? Nor is it easy to understand its evolution on Lamarckian grounds, since a complete egg capsule would hardly have been moulded around an embryo when the latter was already so perfectly grown that the elaborate capsule could have been but useless.

Third: In the fertilization of the egg. Polyspermy occurs, but judging from stages in the male pronuclei the sperms do not enter the germ simultaneously: and thus fertilization takes place during an appreciable interval of time. Moreover, the supplemental sperm nuclei undergo at once amitotic division, whereas in sharks amitotic division follows only after a series of gradually changing mitotic divisions.

Fourth: In segmentation. Cleavage lines appear only after several divisions of nuclei have taken place. In this regard *Chimæra* behaves somewhat like the highly specialized ray among recent Elasmobranchs.

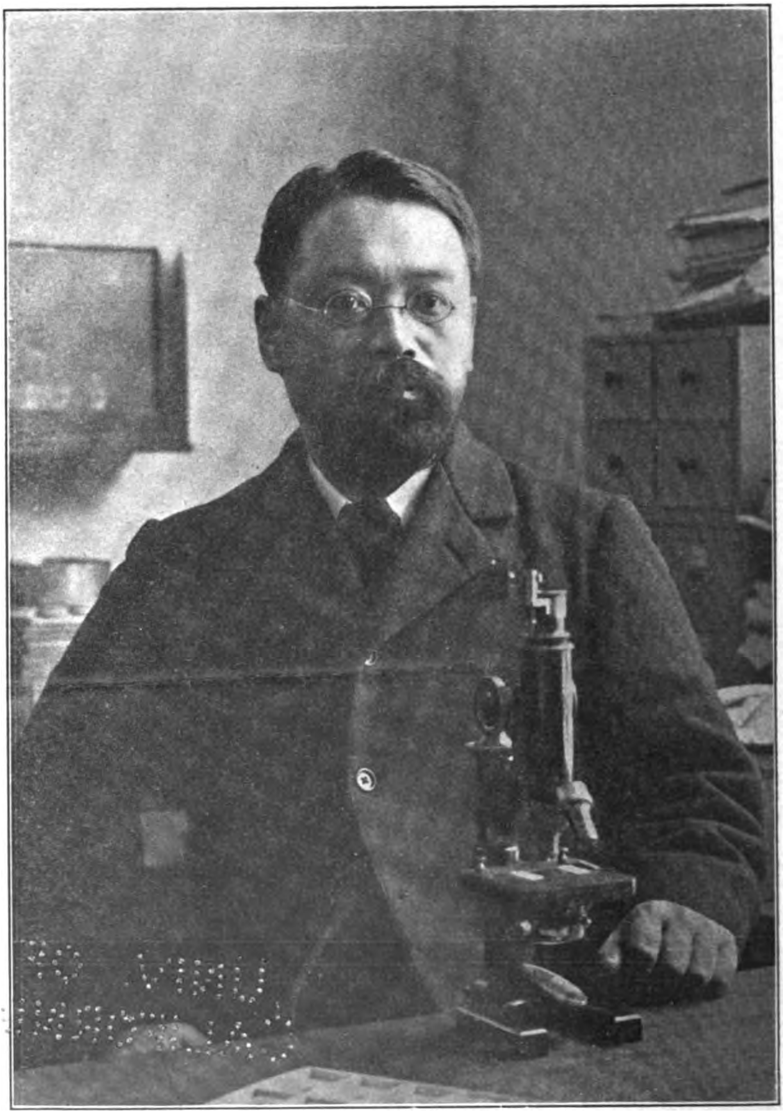
Fifth: In the precocious growth of the embryo. An embryo which, with its attached blastoderm suggests stage *B* (Balfour) in the shark, is intrinsically much more perfectly developed *e. g.* in the details of its head, heart region and tail. In spite of minute size, it resembles more closely the shark stage *D*. The chimæroid embryo tends, accordingly, to assume its ordinal characters at a very early period, and in this regard it is to the shark as the teleost embryo is to the ganoid.

Sixth: In the early arrangement for the nutrition and development of the blastoderm, for it is found that the conditions of the periblast are remarkably complicated. Thus, it is found that even in an early stage of the blastoderm, one corresponding to *B* in shark, the yolk nuclei are already widely different in different subgerminal regions. Especially clear is the way in which yolk cells are contributed to the blastoderm. Into the periphery of the latter are sometimes budded elements of such large size that they can in no way be confounded with the cells of the blastoderm. These cellular increments, moreover, cannot, I am convinced, be confounded with the so-called primordial germ cells, since I have traced their fate and found that in the majority of cases their descendants contribute to the development of the vascular system. Furthermore, in this precocious development of the blastoderm, the laws both of the germ layers as well as of the behavior of amitotic nuclei appear to have undergone remarkable inversion. In the first regard, for example, there is clear testimony that the vascular system is in part (I refer particulary to the vessels which arise hear the middle of the blastoderm) formed from ectoderm. In the second regard, in a large number of cases nuclei whicl have been undergoing amitosis pass into the blastoderm and even ir certain cases continue for a time to undergo amitosis in the blastoderm

As this condition is seen abundantly in all early gastrulæ, and as there are no temporary annexes of the embryo which these amitotic nuclei could form, one is compelled to recall the belief that mitosis is rather useful expression rather than a necessary mechanism of metabolic activity.

Seventh: In provision for the more effective nutrition of the embryo during later stages. Here particularly is to be referred the taking up of nutriment by the embryo *via* external gills and gut. In the shark the yolk material nourishes the embryo largely if not entirely by umbilical vessels. In *Chimæra,* on the otherband, the umbilical mode of nutrition is less conspicuous since the yolk sac is of miniature size. A large part of the egg, it is found, is not enclosed by the down growing blastoderm. And this larger part of the egg, on the other hand, undergoes a process of fragmentation (which follows repeated division of the yolk nuclei), resulting in the production of a creamy fluid which bathes the embryo and in which, therefore, the external gills are freely exposed. Interesting accordingly, is the fact that in the gill filaments are found at various points large blood knots in which numerous hæmacytes are found undergoing division. It may be mentioned also that for a considerable period the yolk laden ventral wall of the gut buds off directly into the gut lumen many small yolk masses, which, judging from mitoses in the adjacent wall of the gut, are of nutritive value. These conditions, it may be mentioned, are, as far as is at present known, unique in the vertebrate line.

UNIV. OF CALIFORNIA



KAKICHI MITSUKURI. 1858–1909.

[Reprinted from THE POPULAR SCIENCE MONTHLY, December, 1909.]

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KAKICHI MITSUKURI, 1858–1909

IN Tokyo on September 16, after a long illness, died Kakichi Mitsukuri, professor of zoology in the Imperial University, dean of the college of science, and the foremost zoologist of Japan.

Any one might safely have predicted that Mitsukuri would succeed. For he came from stock which was both intellectual and energetic. For generations his family had produced prominent scholars, especially physicians, and I recall that one of his forefathers had learned the Dutch language and was translating works in surgery and anatomy in the days of the early Tokugawas, when such exotic studies were punishable with death. It was natural, therefore, that this family with its tradition of western learning should have pushed to the front in the enlightened upheaval of the restoration. Of its youngest members Mitsukuri and two of his brothers were among the scholars who sought the training of foreign universities. They were better by one than *par nobile fratrum*, those young Mitsukuri, and if they could have looked from their ship into the waters of the future they would have seen themselves high in the counsels of a new and national university, one of them a dean of a college, another a peer, minister of education, and president of a university.

Mitsukuri Kakichi, as he is known in Japan, owed his training largely to the United States. He received his first foreign education in Hartford—he was then but a boy and was in the care of the Misses Goldthwaite, to whom his gratitude was ever almost filial. In 1875 he entered the Sheffield Scientific School, and took his degree of Ph.B. in 1879. The same year he matriculated at Johns Hopkins and studied with Brooks and Newell Martin for four years. In 1881 he became fellow in biology: he took his degree (Ph.D.) in 1883. It may be mentioned that his thesis "On the Gills of Nucula" has not fallen into the limbo of forgotten dissertations. In his Hopkins days he was an enthusiastic frequenter of the Chesapeake laboratory, and was an intimate of his fellow students, Fessenden Clark, Sedgwick and Wilson. After this he traveled in Europe, visited universities, English and continental, and thence returned to Japan. There he arrived at an opportune moment: the department of zoology, which had been organized by Morse and given a second bent by Whitman, was in a state of upheaval. Japan in general was beginning to assert her intellectual rights: from the imported foreigners it had learned nearly all it felt the need of, and in this instance there seemed no reason why one branch of the educational work should not be carried on entirely by Japanese. Mitsukuri entered into the work with his new training, and with a knowledge of Japanese diplomacy and breeding and obligations which no foreigner, at least in those days, had mastered. So it came about that the department of zoology began a new development, and in this work Mitsukuri would be the first to testify how much he owed to his closest friend, Professor Iijima, and his other colleagues.

Mitsukuri devoted much of his life in Japan to his numerous pupils, sacrificing to no little degree his research work. He was tireless in his attendance at the university, accessible at all times, and with an affectionate friendliness which no one appreciates more keenly than a Japanese. "I feel I have lost a parent," writes Dr. M—. And this is the prevailing sentiment among his pupils. His attitude was ideal: he was frank, inspiring, uncompromising when a question involved accuracy or scientific purpose. "How different," he would say, "is the training of the diplomat and the scientist—the one studies to dress up the truth, the other to expose it naked." In spite of his long years of foreign training ("*because* of it," he would doubtless have said), Mitsukuri was intensely Japanese—patriotic to his finger-tips, alert in pointing out the advantages of his country's ways, but like Okakura, so skilful in dissecting the failings of his foreign friends that they never minded the pain. None the less, I have still the feeling that the Japanese looked upon him as somewhat too progressive. He admitted foreigners among his most intimate friends, he had rooms in his house in foreign style, and his family took its place in social gatherings in the same informal way as in America or Europe. He could even think as a foreigner, and he certainly could write as one, for his English never betrayed him. And he had a wide circle of correspondents for whom he was constantly doing, and with the greatest courtesy, troublesome favors.

For zoology in Japan Mitsukuri did these things: He directed the upbuilding of the zoological and, to a certain degree (as dean of the Science College), the scientific work of the university; he organized zoology in Japan, making his department its focus, not in technical matters only, but in popular and semi-popular as well; he was the moving spirit in sending zoological expeditions throughout Japan from Sagahalin to the Liu Chiu islands—even to Tai Wan; he was conspicuous in founding and developing the Misaki Biological Station; he was potent in building up a fisheries bureau, officered it with his pupils and contributed to its publications; he gave an important stimulus to the pearl industry in Japan and furnished numerous ideas to the culturists who sought to produce natural pearls by artificial means; and he served effectively on the International Seal Commission. Last of all, he lifted up the position of zoology throughout the country by means of his teachings and by means of the influence he exerted through many friends in all stations. In this regard it has been said he had not a few personal attributes of our own Professor Baird.

His researches cover many branches of zoology. At the time of his death he was completing a monograph of the holothurians of Japan. "We must do systematic work," he said in mock apology, "for you know that nearly everything we find here is new, and it will be decades before we outgrow the zoological age of Linné." But his great work was undoubtedly reptilian embryology—indeed his papers on the gastrulation and embryonic membranes of turtles have become classic. Here, for example, he first gave the correct interpretation of the primitive streak, discovering the rudiment of the yolk plug and enabling comparisons, on the one hand, with the amphibian, on the other, with the avian type. Here, also, he gave the first satisfactory explanation of the relation of the archenteric to the subgerminal cavity, and the peculiar growth of the sero-amniotic canal, which, by the way, one of his pupils afterwards demonstrated in the chick. It is in a manner the test of the bigness of Mitsukuri that with keen interest in his purely morphological work he did not fear loss of dignity by contributing to econ subjects. A delightful little pape his report on Japanese oyster cult quite after the fashion of his teacher, Professor Brooks. [B.]

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OBITUARY NOTICE OF A LUNG-FISH.

By PROFESSOR BASHFORD DEAN,
COLUMBIA UNIVERSITY.

[Reprinted from The Popular Science Monthly, May, 1903.]

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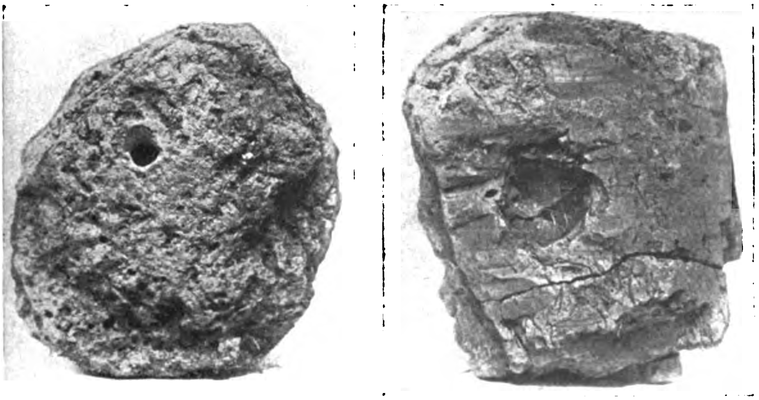
OBITUARY NOTICE OF A LUNG-FISH.*

By Professor BASHFORD DEAN,
COLUMBIA UNIVERSITY.

THERE died recently in the aquarium room of the department of zoology of Columbia University, a specimen of the African lung-fish, *Protopterus annectans*. Here it had lived for nearly five years, thriving at the cost of generations of living earthworms and increasing in size nearly three-fold. From the fact that this interesting fish is relatively rare in aquaria, the present specimen is possibly deserving of a formal memorial notice.

It arrived at Columbia University in July, 1898, in a sun-baked clod of earth, in which under native conditions the fish lies dormant during the summer drought. In this state it had been living for several months, and during the interval it had been breathing air, thanks to its lung, in a very unfish-like way. Its earlier history may be written with tolerable accuracy. Its early life was spent in some African stream in the region of the Congo, where it had lived successfully

Fig. 1. Fig. 2.



Clod of Earth containing Cocoon of Lung-fish. Fig. 1 shows entrance burrow, Fig. 2 remains of cocoon after escape of fish.

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* The lung-fish is generally regarded as a little modified survivor of the ancient 'connecting link' between the water-living fishes and the air-breathing and four-legged amphibians. There is the clearest evidence that in the early geological periods the lung-fishes represented a flourishing stock both in numbers and kinds. At the present day they are reduced to three genera, one Australian, one South American, and one African.

hunting and unsuccessfully hunted, until the approach of the dry season. Then as the stream dried up, it had taken to the last pool, and when this in turn had dried, the fish, like its neighboring friends and relatives, had burrowed deep into the thickening mud, rolled itself up into a ball, secreted a mass of mucus about its coiled body, and made ready for a summer 'sleep.' One of its first precautions was to keep its nose uppermost and to see that its 'breath' found a passageway out of its slimy capsule into the open burrow: in this way, then, it could breathe throughout the summer, while awaiting dormantly the return of rains, and the melting of its 'cocoon.' In this stage in its history it came to be dug up, and, together with other cocoons and their surrounding clods of earth, was crated and shipped to Europe. I am told that the shippers take pains to surround the crate with iron gauze to preserve the fish from the attacks of rats on shipboard, and that the clods of earth are disposed in such a way that the sides containing the breathing apertures face outward so that the imprisoned fish run the least possible danger of becoming stifled.

The present shipment came into the hands of Professor H. O. Forbes, Director of the Public Museums of Liverpool, and through his kindness the present specimen was donated to Columbia. A photograph, Fig. 1, shows the cocoon just as it came to the present writer. The tubular burrow through which the fish worked its way into the mud is seen conspicuously, and one may note that it was somewhat crooked, in spite of the fact that part of its margin has been broken away in the present specimen. Its usual length appears to depend upon the character of the bottom; from two to five inches are the measurements stated. At the end of the burrow lies the cocoon, a roundish mass, brown in color, paper-like in texture, but greatly roughened on its outer surface by attachment to rootlets and foreign matter. Its inner surface, as one would expect from the mucous nature of the shell, is found to be smooth and delicate. Where the cocoon meets the outer burrow its shell is somewhat flattened, and here, near the side, it is perforated by a delicate straw-like tube, formed of dry mucus, which passes downward into the mouth of the fish, and through this the fish respires during the dry season. It has, indeed, been shown by Professor W. N. Parker that this tube passes within the mouth of the fish and conducts the air to the entrance of the fish's lung.

In liberating the fish from the cocoon, the usual procedure is to allow the mass to remain in warmish water until the earth softens and melts, but in the present case a shorter, but somewhat more perilous, course was adopted. One side of the block was cautiously sliced away until the side of the papery cocoon became visible: then the earthy margins of the opening were carefully removed, so that the process of liberating the fish could be observed. The entire mass was next placed in an aquarium in water slightly warmed. In a few moments slight movements of the fish could be seen through the papery shell; and upon lifting out the earthen block and touching the cocoon, a distinct croaking sound was heard several times. Replaced in water, the capsule soon softened and ruptured like wet paper, and for a moment a glimpse was had of the fish tightly rolled up, with its tail folded over the head and only a single thread-like limb protruded. This, however, was but for a moment, for with an energetic squirm the animal liberated itself and sank to the bottom of the aquarium. For a moment it lay motionless, then swam briskly around the aquarium, coming to the surface several times and gulping air. At this time it showed the crimson flush of blood in the tail region where, according to Wiedersheim, the skin aids the lung as a respiratory organ. The fish, as one might indeed have inferred from the size of the burrow in the clod of earth, proved to be small, measuring a little over five inches in length. It was, however, larger than one would have estimated from the diameter of the tubular opening and from the actual size of the cocoon, the latter measuring about two inches in length and one inch in thickness. In Fig. 2 is shown the remains of the cocoon after the escape of the fish, the upper portion of the papery case alone being preserved.

From the small size of the fish this was possibly its first season of æstivation. How long it had been out of the water was not known, but certainly this was a matter of several months. I have, indeed, learned from Dr. Forbes that a fish will sometimes survive a period of eight months out of water.

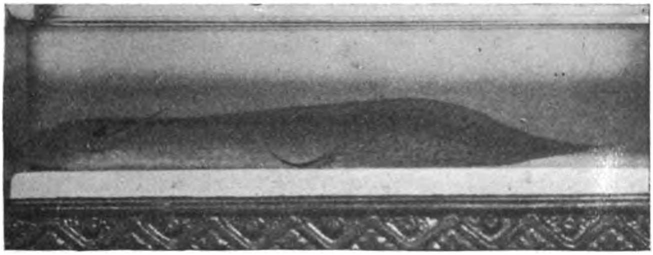

FIG. 3. LUNG-FISH, *Protopterus*. Resting position in aquarium.

Shortly after its release from the cocoon the writer's colleague, Dr. Edward Leaming, took a number of photographs of the fish, some of which are shown herewith, to give a graphic idea of its appearance and unfish-like movements (Figs. 3 to 6). In side view, Fig. 3, the fish is shown in a position of rest, its body resting upon the bottom, its long, paired extremities extended out, braced against the glass side of the aquarium. When moving, however, the fish would lift its body by means of the paired fins, and these would then serve after the fashion of the arms and legs of a quadruped as the fish ‘walked’ slowly about, alternating the forward and backward movements of its extremities. This condition is illustrated in Fig. 4, in which the bend of the arms and legs, where they support the weight of the fish is shown satisfactorily. In this figure, which, together with Figures 5 and 6, were photographed from almost directly above the fish, one observes that the strain upon the limbs falls, not upon their tips, but near the middle. Thus one notes in Fig. 6 that the tip of the right-hand pelvic limb curls upward and is free from the bottom. One observes especially in Fig. 3 the stress upon the left pectoral limb, which causes it to be bent almost at right angles in an elbow-like fash-

Fig. 4.

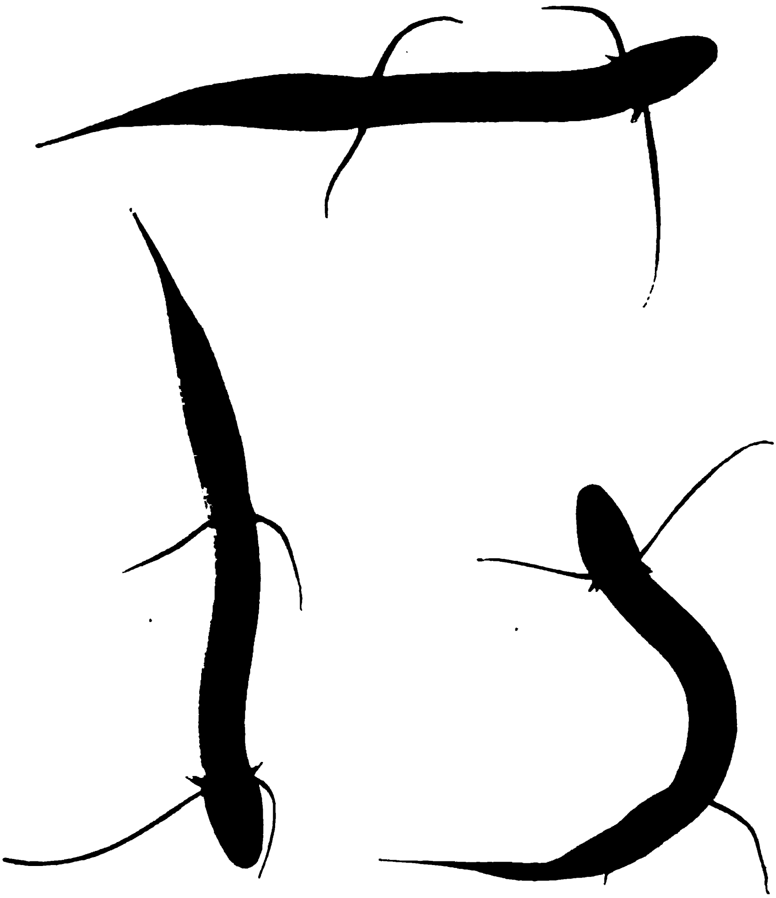

Fig. 5. Fig. 6.

Lung-fish showing Various Movements.

ion. This limb, by the way, has lost its tip, and is being regenerated, the lighter portion, as shown in the figure, having already been grown. I might note that at the point where the injury occurred a small transverse branch later made its appearance, but after this had grown for a year or two and become one eighth of an inch in diameter, it gradually degenerated and finally entirely disappeared. A characteristic movement is illustrated in Fig. 5; here the fish, having reached the end of the tank, draws back before turning in another direction. To accomplish this result, the fins again operate in a quadrupedal fashion: pressing on the limbs firmly, the fish recoils, pushing itself back by means of its shoulder and pelvic muscles, the tail and body taking little or no part in the process. In this figure we again note the strain which is laid upon an extremity, for the left arm is bent almost to the shoulder.

Another characteristic movement is pictured in Fig. 6, where the animal is circling around. The weight of the hinder body is supported firmly by the outstretched legs, and the arms swing forward and backward, turning the anterior part of the body. In the present position the animal is on the point of again advancing, and in this event the limbs will move alternately as shown in Fig. 4. Throughout these varied movements the fish is slow and deliberate, reminding one rather of a newt than of a fish. In the present figures attention should be called to the great length of the uninjured arm, which in this small specimen indicates doubtless a larval feature of the fish. Also noteworthy is the position of the external gills, which stand out at the sides of the head very much as they do in a larval salamander.

From this stage onward the life of the lung-fish was a rather uneventful one. It received its daily diet of earthworms with apparent relish, and upon them it thrived and grew. Its yearly increase in size varied between two and three inches; at the time of its death it measured eighteen inches. Its movements in the aquarium were like those of larval salamanders, axolotl, for example. Only on rare occasions did it swim in a fish-like manner by means of caudal fin and undulating body, and only twice a year did it show of what sudden movements and great activity it was capable. On these occasions it was taken from the tank and carried to or from the New York Aquarium where, through the courtesy of the officials, it was kept during the summer. Cold weather, as might be inferred, it was least capable of enduring. On several occasions during winters, when the temperature in the aquarium room became less than 50° F., the fish was found in a semitorpid condition. It was then taken out and handled with scarcely a movement, but was revived by immersion in warm water. It gave its attendant no uneasiness on the score of appetite, for it took its food with clock-like regularity. Its great difficulty, however, appeared to be due to defective eyesight, for even though a moving worm were put in its immediate neighborhood, the fish did not appear to detect its presence through the sense of sight. At first, stimulated probably through its lateral line system, the fish seemed to feel the movements of the earthworm; it would then turn in the direction of the food, move towards it with apparently increasing enthusiasm, but when only at close range did it seem actually to see the prey. The fish's movements in feeding reminded one rather of a turtle than of a fish, or, best of all, of its kindred salamanders. Eyeing the moving worm steadily, it would make a sharp snap at it. If this movement failed, it would appear to deliberate, gaze fixedly at the object, and snap again. If more successful this time, it would pause with the food in its mouth, then with a series of accelerating snaps, the entire worm would be ingested. Occasionally a worm would be cut entirely in two by the quick snap of the fish's powerful jaws, and this would result in the loss of the worm and in the feeding beginning anew. During this entire process the fish's arms would be spread widely apart, so as to support the weight of the head.

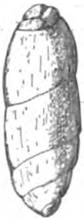

FIG. 7 *a*.

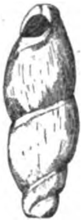

FIG. 7 *b*.

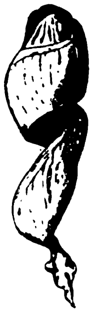

FIG. 7 *c*.

In later years the fish became quite tame, and would feed out of the hand of the laboratory attendant, who always maintained that the fish distinguished him from other visitors. Certain it was that he finally accustomed the fish to a diet of raw meat, and this substitute for earthworms proved a convenient one during the cold season. A finger thrust into the aquarium and stirred vigorously would be enough to attract the fish's rather sluggish attention: it would slowly leave its resting place, 'walk' toward the region of the disturbance, rise to the surface and after giving the usual evidence of bad eyesight would finally get its mouthful of food. The fecal material of the fish, one might mention, showed the cast of the spiral intestinal valve which in lung-fishes is almost as well developed as in sharks. Possibly, therefore, some of the coprolites from early geological horizons which have generally been referred to sharks may have belonged to contemporary lung-fishes. The fecal material at the time it is deposited appears as in Fig. *7a;* after remaining in the water for several hours it presents the appearance *7b,* and finally, after twenty-four hours, uncoils as in Fig. *7c.*

The air-breathing movements of the fish were irregular. At times it would come to the surface about every five minutes and swallow a mouthful of air; then again several times this period would elapse before the fish would rise to the surface. In all cases escaping air passed out through the gill clefts, usually through those on the left side.

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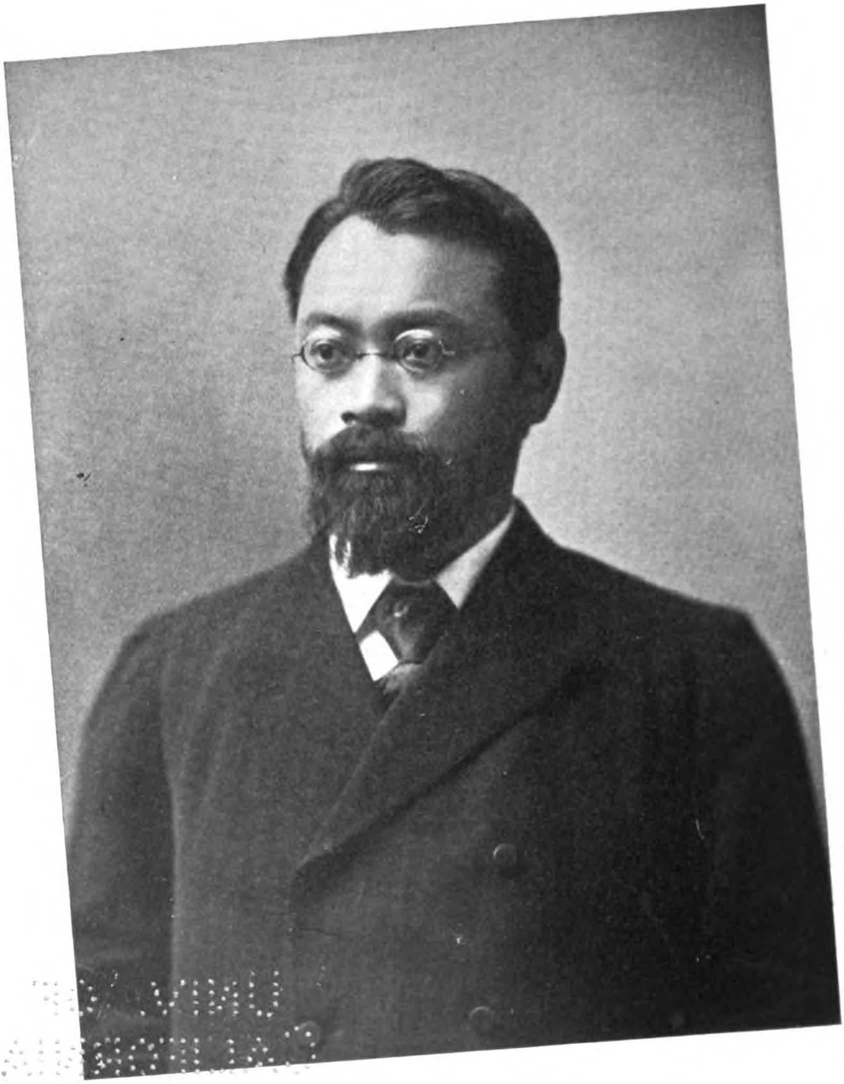
A VISIT TO THE JAPANESE ZOOLOGICAL STATION AT MISAKI

By Professor BASHFORD DEAN

[Reprinted from The Popular Science Monthly, July, 1904.]

UNIV. OF
CALIFORNIA



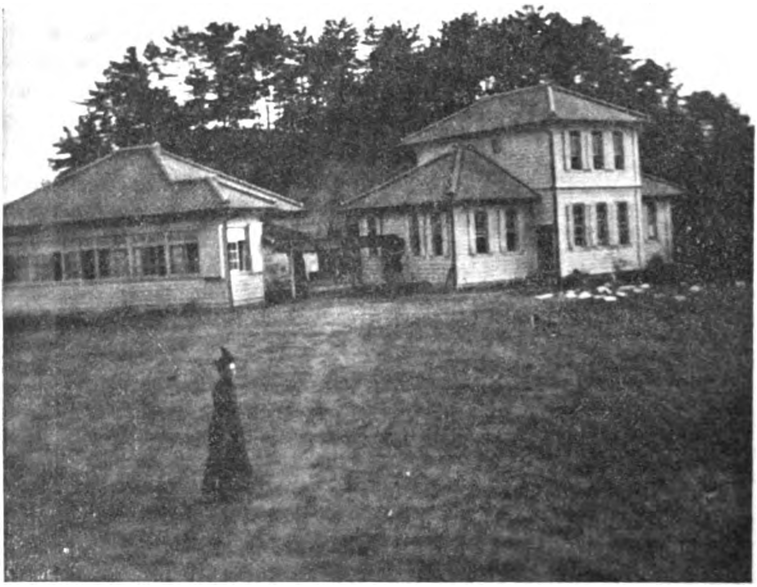
K. Mitsukuri Boston, 1898

[Reprinted from THE POPULAR SCIENCE MONTHLY, July, 1904.]

A VISIT TO THE JAPANESE ZOOLOGICAL STATION AT MISAKI.

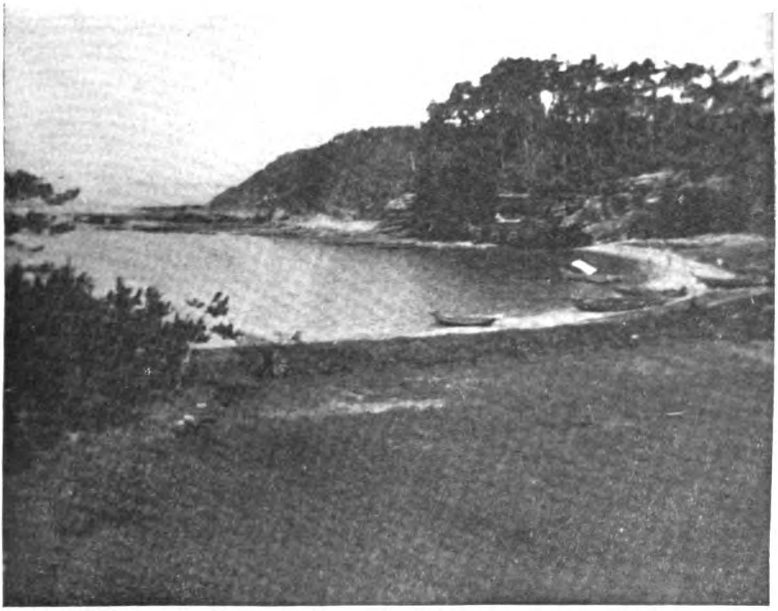
BY PROFESSOR BASHFORD DEAN,
COLUMBIA UNIVERSITY.

JAPAN is not at its best in the rainy season. For the rain comes down in floods. And my first impression was that Misaki was a larger aquarium than even a zealous naturalist needed. We had left Tokyo at six—I was about to say, early one morning, but I recall that six is not early in Japan—on a small bay steamer which plies daily to Misaki. And a few hours later we had about reached a climax in our rolling, when, turning suddenly, we ran under the lee of an island and came to anchor. I confess that I was not cheered by the glimpse of Misaki; the town was a flat, sodden mass of thatched houses, its background an abrupt knoll, with a ragged skyline of dripping and irregular pines, and the drooping eaves of a temple. And to add to the dismalness of the picture, even the sampan men appeared tearful as they shedded streams of rain from the points of their porcupine-like coats. Our fellow passengers, on the other hand, showed not a symptom of discomfort, and they clambered smilingly into the sampans, standing or crouching under a mass of oil-paper umbrellas, men often tucking up their kimonos and standing bare-legged like storm-bound birds—their wide wooden clogs giving them the appropriate webbed feet. Ashore was waiting for us an assistant of the station, Mr. Tsuchida, and together we waded through the narrow and fishy streets of the town (which I found, to my surprise, had a population of five thousand, and was of no little commercial importance in furnishing fish for the Tokyo market) to the Inn Kinokuniya. This inn I recall vividly, for its host, in spite of the drenching rain, thought it necessary to hunt the town for a knife and fork for the foreigner, and while about it borrowed a chair and table, probably from the station house and its solitary policeman, and provided 'beefu teki' and 'pan' (bread), in order to make things homelike, as he said. And while he busied us with these incidentals, he engaged a sampan to carry us to the station. I might mention that in *real* Japan the traveler can, or should, do little without the aid of his innkeeper—if one wishes to go to the railroad, a theater, a shop, or to hire a boat, a coolie, a jinrickshaw—it is *de rigeur* to go first to the ever-present inn. I soon discovered that our host was on excellent terms with the zoological people, for the station had formerly been located near by in the town. But the town was found to be not the best of locations; there was too much noise, and—fish market, for example—so the building was moved bodily around the point to a small rugged peninsula which forms the harbor of Aburatsubo, about a mile away. Presently our host shelled us in rain coats and deposited us in our sampan, and our ferryman, sculling with a heavy balanced oar, shot us beyond the island, whose lighthouse guides the steamers into the mouth of the bay of Tokyo, and then, turning sharply, he skirted the coast, around the edge of the sea of



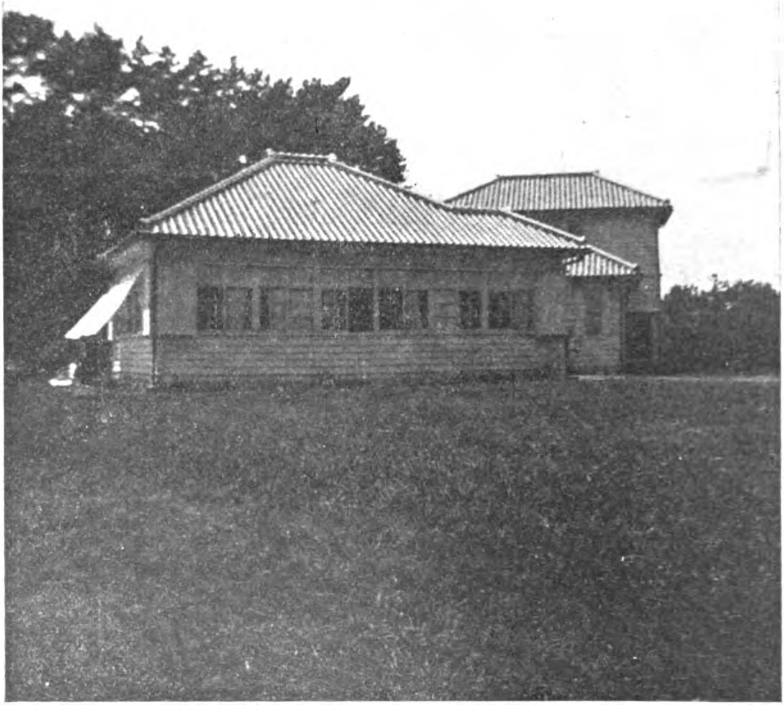
THE MISAKI ZOOLOGICAL STATION.

Sagami. At this point of the trip I recall that some confusion was created, as we rounded a swell-swept rock, by our sailor falling overboard, his oar becoming suddenly unshipped, an incident remembered mainly on account of the poor fellow's embarrassment. We pulled him into the boat and reinstated him; and he shook off his dripping kimono and stood naked in the drenching rain; bronze body, white loin cloth, white band knotted around his forehead, pressing down a fringe of bristling black hair, his muscles showing splendidly as he swayed at his oar, hissing viciously as he pushed and pulled. In a few minutes more we rounded a little pine-covered point, and the two white buildings of the laboratory came into view.



Beach of the Castle of Arai, Seen from the Station.

The taller of these, two-storied, is the one which was removed from the town of Misaki in 1897, the other was built a couple of years later. Together they stand close to the water, but are sheltered from typhoons by an abrupt hill which forms the end of the point. The surroundings are beautiful. A number of inlets cut deeply and irregularly into pine-covered hills, and in nearly every direction one obtains vistas of bluffs, pines and rocks very much as at famous Matsushima. Altogether I believe that the student here enjoys more picturesque natural surroundings than at any other laboratory in the world. And we may add to this the unzoological item that the headland has a romantic background. For here was the castle of Arai, famed in Japanese history as having withstood for several years the siege of the Hojo regents during the fourteenth century: and on every hand are memories of its past glory.



The Marine Station at Misaki.

If I digress a bit, I might point out that the student dormitory, amid the old pines on the hilltop above the laboratory, and next to Professor Mitsukuri's villa, is built on the exact site of the ancient castle, and here interesting relics have been found; such, for example, was a fragment of a splendid gold-crested helmet dug up during my stay. Near by are traces of fortifications, and a store-room excavated in the rocky bluff during the ancient days of the castle. The bay, at the side of the laboratory, is still called the 'Red Harbor,' because at its very edge the defenders were beheaded after the sack of the castle. And just opposite is the 'Buried Treasure-Beach,' where the most valuable plunder of the castle is supposed to have been stored. And more interesting still are the monuments marking the spots where died by hara-kiri the lord of the castle, Dōsun Miura, and his son, after word had been brought them that all hope was lost. The local story is that Dōsun Miura retired to this point after witnessing the death of his son, and fearful lest his own head should be carried across the bay to Odawara by the conquerors, he would trust no one to act as his second in the death ceremony. Seizing his short cue with one hand, *he is said to have cut off his own head with the other, and to have thrown it far out in the deep water before his body fell,* a physiological possibility, by the way, which students of the laboratory do not question—in the presence of townspeople. So the greatness of the Miura is unimpaired, and every year memorial services are celebrated on the laboratory grounds. At this time portrait-images of Dōsun and his son are brought from a neighboring temple and placed on the altar in a prayer-tent near the beach, and wrestling bouts commemorate the siege and the fall of the castle. Perhaps I might end my digression with the note that the present property came into the hands of the imperial family and has remained unoccupied since the fifteenth century. The major reason for this is said to have been that the point was haunted and many curious stories are told of the reappearance of Dōsun Miura and his men on the hilltops among the ancient pines. One recognizes them readily, since, like all Japanese specters, *they have no feet.* Indeed, I learned through Mr. Alan Owston, of Yokohama, that even a few years ago, when his yacht anchored overnight at Aburatsubo, the point was still so ghost-ridden that the sailors were unwilling to go ashore!

As for the zoological station itself: The one-story building is used by the graduate students, and is divided off in alcoves in the usual way. Work places for eight investigators are provided on the north side of the main room. On the south side of the building is the office of the director, and forming the fourth corner of the building is a concreted room containing aquaria and giving ample space for the preparation of larger material. By a covered way one passes from the door of the advanced laboratory into the two-story building, the ground floor of which is used at the present time for general class work. The upper story contains two living rooms fitted in European style, which were generously placed at the writer's disposal by the authorities of the Zoological Institute.

The general class work consists of a summer course of about six weeks' duration, which gives its members an opportunity of becoming familiar with the structure of the prominent animal types. The stu-

'Arai,' the Collecting Boat of the Station.

dents, about thirty in number, are usually teachers of zoology in various high schools throughout Japan. Some of them live in the dormitory on the hilltop, others find lodgings at the neighboring fishing village of Aburatsubo, often hiring quarters in the little temple on the top of

A Fishing Boat.

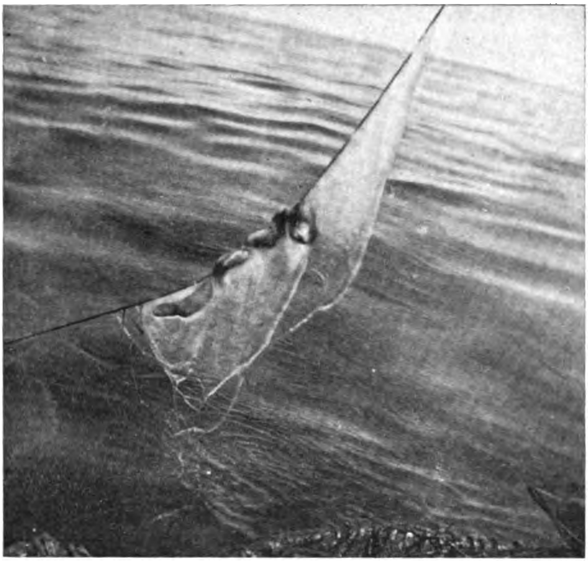
the hill. The investigators include Professor Mitsukuri, one of the founders of the station and its director, and usually the greater number of the staff of the zoological department of the Science College. Professor Ijima frequently comes down to visit his reefs of glassy sponges, Professor Watasé, Professor Goto, Dr. Izuka, Dr. Miyajima, Mr. Namiyé, some of the younger assistants, and three or four of the graduate students of the institute at Tokyo make up the remaining corps of investigators. During the writer's visit, a Russian ichthyologist, Professor P. Schmidt, became a guest of the station, and an American zoologist, Mr. J. F. Abbott.

A Crew of Fishermen.

The work-quarters, it may be mentioned, are simple, but all necessary appliances and books are promptly forwarded from the institute at Tokyo. It is the collecting facilities which the visitor does not forget, for not only is the locality a rich one, but the ways and means are at hand to secure material even from great depths. And in this lies the value of neighboring Misaki, for during many months of the year the fisher people set out at sunrise in their large boats, proceed off shore to well-known fishing reefs, which, by the way, are often in very deep water, and return during the afternoon with a varied haul. If successful, their home-coming is spectacular—they chant in chorus and push their heavy boat through the water, sometimes skulled by as many as a dozen oars, at the rate of a young steam launch, the boat garnished at the prow, and the crew wearing fillets and loin cloths of scarlet. It happens, fortunately, that the fishery is carried on principally by hand trawls, for it is clear that when such a line, which is sometimes a mile in length and with thousands of dependent hooks, is pulled up again, even if fish are not taken, there will surely be entangled a varied collection of objects—sponges, echinoderms and rock fragments, the last often richly stocked with brachiopods, worm tubes, corals, bryozoa. Happily, too, the collector of the station, Kuma Aoki, is an ex-fisherman, for, knowing the townspeople, he serves as a diplomat, suggesting regions which should be fished, and often accompanying the expeditions. To be mentioned in this connection is the skill with which the fisher people are able to locate accurately fishing grounds. By the use of a system of cross ranges, a master of the craft like Kuma can return to a spot where he has lost a valuable fishing line, and can secure it on a following day—a result which seems the more remarkable to the novice when he reflects that the line may have been lost in 400 fathoms of water.

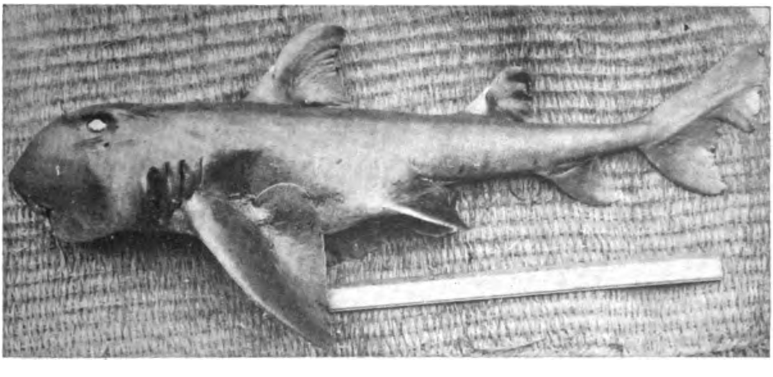
While the trawl line is the customary apparatus of the fishermen, numerous devices are also employed in special fisheries, an account of which has been given recently by a Russian ichthyologist (cf. Dr. P. Schmidt, *MT. d. Deutschen Seefischerei-Vereins,* No. 2, p. 31, 1903). I might mention particularly the use of earthenware urns which are fastened together by straw rope, and sunken in the coves in the neighborhood of the station. These are constantly used by octopus as places of retreat during bright daylight, and to secure them the urns have merely to be overhauled from time to time. Shell fish are often taken in the usual eastern way by the use of a water glass and a dart-pointed bamboo pole, or, without a water glass, the fisherman may simply thrust his head below the surface of the water. Especially useful to the collector are the numerous divers of Misaki, who are, I may add, so skilful that they use no apparatus, not even weights for rapid descent, but will swim down duck fashion, to a depth of twenty or thirty feet. They hunt especially *Haliotis,* examining the rocks deliberately, and often remaining below several minutes. I may mention that one of the familiar sounds which one hears when rowing in the neighborhood of the station is the diver's peculiar whistle, by which he expands his lungs before descending.

One need hardly review the fauna in the region of Misaki. It is enough, perhaps, to say that here focus many favorable conditions for



A Living Hag-fish, Showing a Mass of Freshly Secreted Slime.

marine collecting. There is a rich shallow water fauna which yields, among other delectable things, *Amphioxus,* sea-pens, a giant *Balanoglossus, Onchidium* and a *Phoronis* four inches in length. In the immediate neighborhood of the station can be obtained at low tide *Antedon,* very abundant, *Lingula,* the spawning of which Mr. Yatsu has observed in the laboratory, and *Cœloplana,* the latter discovered by Mr. Abbott. Pelagic forms can also be collected favorably. *Pyrosoma, Appendicularia* and *Salpa* are abundant. Various ctenophores, including *Cestus,* are not uncommon, and near the station, sometimes sweeping close to the shore, is the Black Current, bringing many southern forms. I may mention that the dead shells of *Nautilus* have been



A Freshly Caught Port Jackson Shark.

picked up near the station. The richness of the neighborhood in deep-water forms has been well known since the studies of the *Challenger*. Glass sponges of many species are frequent prizes of the fishermen. And stalked crinoids (*Metacrinus rotundus*) are often taken off the reef Okinosé. Among the fishes *Bathythrissa,* a primitive deep-water teleost, of which the *Challenger* was able to obtain but few examples, is now taken off Misaki so abundantly that it is regularly shipped to the fish-market in Tokyo. Hag-fishes are common, even more than common, and there have been collected within a relatively small area three genera and four species. Among the sharks *Heptanchus* is common; *Mitsukurina,* which is perhaps the Cretaceous broad-nosed *Scaphanorhynchus,* is taken occasionally. A Port Jackson shark is abundant, and in the course of a year the neighborhood yields about a dozen specimens of the frilled shark, *Chlamydoselachus.* Of chimæroids, *Chimæra phantasma* is common, and *C. mitsukurii* and *C. purpurescens* also occur; rare, however, is the long-nosed chimæra, *Rhinochimæra pacifica.*

One need hardly remark that the possibilities of Misaki are not exhausted in producing new and extraordinary forms. To cite merely an instance of this, during the writer's visit two hag-fishes were obtained, one of which, *Paramyxine atami,* was transitional between Myxine and Bdellostoma—its outer gill openings being drawn together within the length of about a centimeter; another (*B. okinoseana*) was transitional between the hag-fishes of many and of few gills, a large form with eight gill-openings on either side. In fact, it is coming to be expected that each year is to bring to the Zoological Institute at Tokyo prizes from Misaki—one year new forms of sponges; another, a gigantic tubularian hydroid, *Branchiocerianthus,* as a 'gift from the sea goddess Otohimé'; and another, specimens of umbrella-shaped octopods, *Amphitretus.* Under such circumstances it is not unnatural that the visitor should bring away from Misaki a stronger impression of his individual work in collecting—and this implies a clearer picture of the local fauna—than from many an older and better known zoological station. And he might justly add that the friendship of his colleagues of Japan is not the least enduring memory of his stay.

Compliments of
Bashford Dean

NOTES ON ASIATIC MUSEUMS

By Professor BASHFORD DEAN

[Reprinted from The Popular Science Monthly, Vol. LXXI., December, 1907]

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NOTES ON ASIATIC MUSEUMS

By Professor BASHFORD DEAN
COLUMBIA UNIVERSITY

ASIA, whatever its contributions to art and science, has, humanely speaking, taught little to the west as to either the means of forming its illustrative collections or the manner of displaying them; in fact, as far as I am aware, the trend of Asiatic culture has been rather to deter its people from collecting. For such an interest, to pure eastern ideals, would foster the heresy that the things of this world are to be the more highly prized: or, in another direction, it might suggest undesirable ostentation. It is from the latter point of view, in fact, that a Japanese collector will still decline to exhibit his treasures outside of the circle of his intimate friends. In any event, whatever be the reasons, I think it may safely be said that comprehensive collections were early unknown in the east. In India, land of fabulous riches, the pre-European collections appear to have been confined to the cabinets of rulers and the wealthiest civilians, and were made up largely of decorated objects, ivories, jewels, arms, now and then menageries—the last sometimes including exotic animals. Such collections were usually little more than a gathering of valuable heirlooms, objects obtained during travels, and curiosities generally.[1] And similar conditions prevailed, as far as I was able to find, in China. In Japan, small collections were, and are, very numerous. Professor Morse, knowing his theme more accurately than Huish, describes the Japanese as a nation of collectors; but such collections, as I think all will agree, are notable for their quality rather than their comprehensiveness, and are formed in the strictest sense for private use. In Japan, as elsewhere in Asia prior to the invasion of European methods, there was not, I believe, a single public museum, unless indeed we regard as museums the storehouses of temples. These, however, contained little more than the reserve stock from which objects for temple service or decoration were chosen.

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[1] I recall, as a typical specimen in such an early collection a copy in ivory of a human skeleton which a rajah (of Tanjore) had caused to be prepared in Paris—for a genuine one could not, according to the rules of caste, be used in is anatomical inquiries.

The earliest Asiatic museum appears to have been established in the Moluccas, about half a century after their definite settlement by the Dutch, and in the classic work[2] of Georgius Everhardus Rumphius, written at the close of the seventeenth century, we have a record of the number and variety of objects which had been gathered together by this enterprising collector in the room of curiosities in Amboyna (Amboinsche Rariteitkamer). It is evident that this collection was well represented in mollusks, crustaceans and echinoderms. It contained a number of minerals and a small collection of fossils, the latter representing many groups. The descriptive catalogue of Rumphius, it may be mentioned, is well known to naturalists as containing the first account of the soft parts of the chambered nautilus, accompanied, too, by a figure which for a century and a half proved the most accurate in existence. Few details appear as to the organization of this pioneer Asiatic museum. Its founder was a well-to-do merchant in Amboyna, and it was probably installed in one of his warehouses. As far as I am aware, there is no proof that it was formally opened, in the sense of a modern museum, but by analogy of contemporary collections it is probable that the curiosity room of Amboyna was as freely open to visitors as the similar collections in London, Dresden or Paris.

In India the modern public museum found its definite foothold at the time of the extension of British rule. At the end of the eighteenth century, there were already active collectors among the officials of the East India Company, but in general the material then collected, whether ethnological, plant or animal, found its way into Europe. In the work of Linnæus, for example, we find record of many Indian species which had been sent him by European collectors. It was by such early workers in various Indian cities that societies were formed which became of considerable importance toward the middle of the nineteenth century. And it is to these local societies that the origin of many of the recent museums is due.

In the present paper it is not my plan to refer even in outline to all museums of Asia. Those of Japan are so important that they might conveniently be reserved for a separate paper. The Dutch museums, moreover, I have not had an opportunity of visiting, nor yet those on the continent in the Malayan states. When in Calcutta, I was told by Dr. Annandale of the interesting museum at Kuala Lumpur in Selangor, the federal capital of the Malayan states, which promises to be most complete. A building is here in process of construction, which will make this museum twice the size, for example, of the well-known museum at Colombo. Its present curator is the ornithologist, Mr. H. C. Robinson, formerly of Liverpool. I learned also of the museum at Thai Ping, capital of Perak, which contains a remarkable ethnological cabinet and an extensive collection of Malayan reptiles. This museum, under the direction of Mr. Leonard Wray, is, I was told, one of the most interesting in Asia. The museum at Bankok, on the other hand, is less important, in spite of the apparently more favorable conditions under which it has grown up. And its arrangement leaves much to be desired.

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[2] Amsterdam, François Halma, 1705. Part of the collection, as Mr. C. Davies Sherborn has kindly ascertained for me, was later sent to Europe and sold, 1682, to Cosmo de Medici III. It was subsequently transferred to Austria as part of the Medicean inheritance.

Of the museums in the Dutch East Indies, that at Batavia is easily the first, containing extensive local collections, both ethnological and faunistic. A second museum, at Trevandrum on the west coast of Java, has received the favorable comment of experts. Its collection of whales is especially complete.

The museums in China may be dismissed with but few words. In the Chinese treaty-ports there is little interest in museum matters on the part of resident Europeans, whose ways are commercial, and under existing conditions the Chinese authorities can hardly be expected to grant funds for such purposes. The best Chinese museum is the one at Hong Kong. It has a separate building with well-lighted galleries, and exhibits a fairly extensive series of natural history and ethnological objects, coins, etc. It is clear, however, that its resources are very restricted, and such a museum, whatever its effect upon the oriental visitor, is apt to be uninspiring. In Peking, however, in connection with the Imperial University of China, an important museum will soon be opened; it may be mentioned that this branch of the governmental educational work has been largely directed by the Japanese.

The museums of the following cities may be given a more detailed report, *viz.*, Singapore, Colombo, Madras, Calcutta, Lahore and Jaipur. The museum in Bombay is said to be uninteresting, and I neglected to visit it.

SINGAPORE

The museum at Singapore, known as the "Raffles Museum," had its origin (1844) as a proprietary library in which local curiosities came to be preserved. In 1874 the institution was taken over by the British government (Straits Settlements), and in 1887 the present building was provided to house a collection acquired at the time of the Victorian Jubilee. The building is well proportioned, suitably lighted and planned, Fig. 1, but too small for its needs, and the authorities are now constructing an addition. This will be of the same size as the

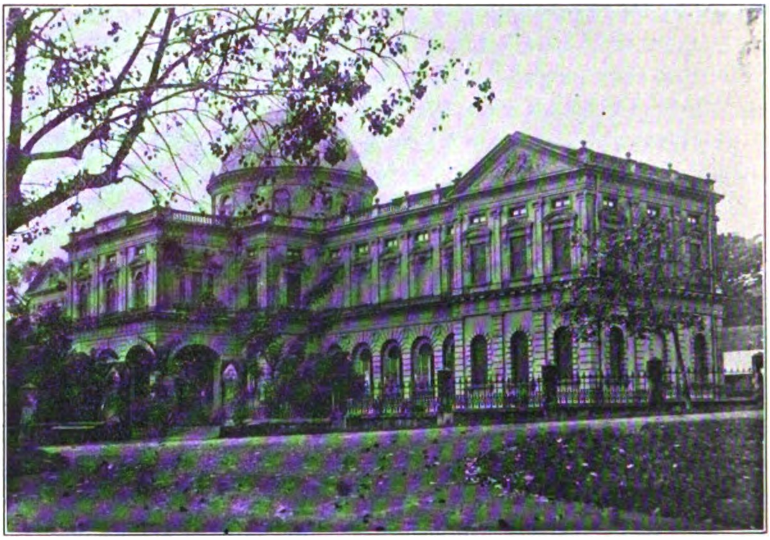

FIG. 1. SINGAPORE. THE RAFFLES MUSEUM AND LIBRARY.

earlier building, and is to be connected with it by a wide gallery passing from behind the main staircase. Each building measures about 250 feet long by 50 feet wide; the cost of both buildings amounts to about $100,000. Building, it will be seen, is distinctly less expensive than in the Occident!

The site of the museum is in a small city park. Entering the building from the town side, one passes into a spacious rotunda well filled with cases, and giving one the preliminary color of the local fauna. Prominent, for example, is a tiger fairly well mounted, and with a jungly background. This huge creature had been, I was told, the household pet of a local Rajah. One may mention, incidentally, that the tiger is decidedly on the increase in the Malay Peninsula, indeed even in the immediate neighborhood of Singapore. The collection of insects in the museum is important. In the rotunda is a series of native beetles and orthopters, including among the former, wonderful longicorns and Scarabœids; and, among the orthopters, the best examples I have seen of leaf insects and walkingsticks. At one side of the rotunda is the entrance of the Raffles library (now grown to 30,000 volumes), which is devoted largely to works dealing with local natural history and ethnology. At the back of the rotunda, one ascends the stairs and enters the natural-history gallery and the ethnological rooms. Among noteworthy exhibits I recall the collection of local butterflies and moths, and a series, possibly the best extant, of paradise birds. The reptiles include turtles, crocodiles, and a great number of local snakes. The cases containing the gibbon and ourang would, I am sure, be cordially envied by the best western museums, even though the mounting is not quite up to the present standard. I recall particularly one male ourang with a splendid head, and of extraordinary size. Among the zoological rarities are the relics of a very young dugong. This had been brought to the museum living and the preparations are accompanied by sketches of the living animal. In invertebrate material there is the usual range of crustacea, corals and sponges, most of them carefully determined. The ethnological cabinet (Malayan) is important, as one might expect, and its arrangement is well carried out. There are models of houses, some with inao suspended about them, suggesting primitive Japanese buildings, even with the curious "frog-thigh beams" crossing at the ridge pole, as in the most primitive Shinto temples, and with these are many suggestions of relationship with Japan. Of Dyak objects there are rich gatherings, including a collection of krisses, costumes, ornaments, etc. There are a number of the sharply-perforated carvings still used to decorate Urala ceremonial feasts, groups of objects used in marriage ceremonies, collections illustrating local basket-making, an art in which the Malayans are especially skillful. There are also cases of native cloths, coins and ornaments of gold and silver, the latter not as good in quality as one might reasonably expect. In the artistic treatment of many of these objects there are obvious affinities with the South Seas. Much of the success of the present museum has been due to the labors during the past dozen years of the director, Dr. R. Hanitsch, whose picture, as he stands in front of his bungalow, near

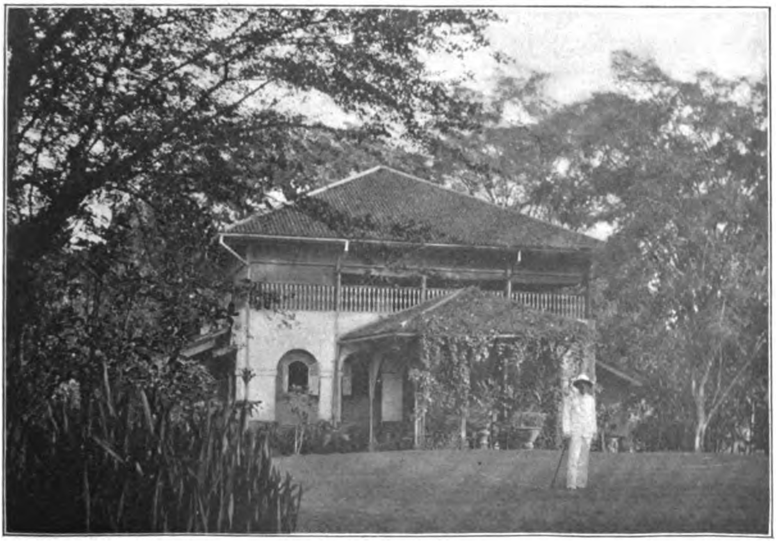

FIG. 2. SINGAPORE. BUNGALOW OF THE MUSEUM-DIRECTOR, DR. HANITSCH.

the museum garden, is shown in Fig. 2. Dr. Hanitsch is a graduate of the University of Jena, and was for many years demonstrator in zoology in the University College of Liverpool. The former director was the well-known ornithologist, Mr. W. Davidson.

COLOMBO

This museum, oldest in its building (1877) and in some regards best of Asiatic museums, was built on the outskirts of the city in the middle of the old cinnamon gardens. It is especially important to the general visitor as giving him the only practicable glimpse of the antiquities of Ceylon. It stands back from the red road, its buff-colored and long two-storied façade appearing prominently against a setting of tropical trees. On the ground floor are arranged the antiquities: in one room are objects in precious metals and stones, arm-rings, necklaces, utensils, caskets, sword handles; and near by are figures dressed in Cingalese finery of early times; on another side is a library containing Ceylonica, and a mass of the ruler-shaped books with palm-leaf pages scratched with Sanscrit; on still another side, in an imposing gallery, is a collection of architectural and decorative objects in wood and stone, including the colossal lion brought from Pollonarna, on whose back the native kings sat when they administered justice. Here also is the beautiful window from the ruin of Yapahoo, and a huge portrait statue of a twelfth-century king. On the walls of the main staircase are copies of the frescoes of the caverns of Sigiri. The collection of antiquities extends even into the garden, where several of the larger statues and a shrine are exhibited. The upper story of the museum is devoted to natural history, and here the distinguished director, Dr. Arthur Willey, has arranged groups of animals to give the visitor an adequate picture of the wild life of Ceylon. Alcoholic and dried specimens are well displayed and labeled, and even living specimens are interspersed, as in a case containing leaf-resembling insects. Dr. Willey has taken greatly to heart the need of exhibiting living creatures in the interest of his museum and, in the garden adjoining his office, he has arranged a small menagerie, which has proved a great attraction no less to foreign visitors than to natives. Nor does Dr. Willey escape his living charges even when he goes to his bungalow, for there I saw a fine series of the rare lemur, *Loris,* as well also as a specimen of *Ichthyophis glutinosa,* the earthworm-like amphibian whose development was studied by the Sarazins.

No one should leave Ceylon before paying a visit to the renowned botanical gardens, with a small museum, at Peradeniya; for it is but seventy miles from Colombo and at a delightful altitude (1,500 feet). For here within a small area one may see, with a minimum of discomfort, the rarest and most striking tropical plants, from minute orchids to banyan trees: and one wanders about as in a land of enchantment, amid traveler's palms, which will spout water if one punctures a stalk, breadfruit, cocoanuts, nutmegs, cinnamon, deadly upas trees, *Bauhinia racemosa,* with its cable-like stems, and the telegraph-plant, *Desmodium gyrans,* automatically lifting and dropping its leaves. Incidentally, too, there are zoological interests. Not uncommon are trees infested with flying foxes: and in the neighborhood the traveler to the east may see his first elephant working in the fields, but willing to show his paces for a few pice; so too one might happen to make the acquaintance of land-leeches, which find their way unpleasantly through the buttonholes of his shoes. But as an offset to this he may see a wild peacock, glorious in color. Or he may discover a cobra and induce it to display its hood.

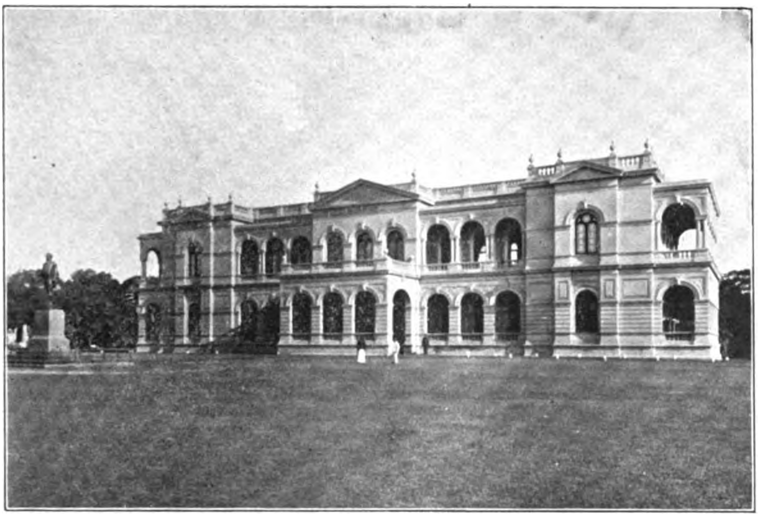

FIG. 3. COLOMBO. CITY MUSEUM.

MADRAS

The museum in Madras is in many regards a quite modern institution. Its buildings are new and spacious, built of dark brick and terra-cotta in Indo-Saracenic style, Fig. 4. Its collections illustrate admirably the natural history, archeology and art of southern India. Included with it, also, is the important Connemara library, rich in material relating to the history of Madras. The natural-history section is the oldest of the museum, part of its collection dating from 1846, Fig. 5, and it has the interest of including within its animal galleries a number of living specimens. The archeological section is rich in prehistoric objects, especially pottery: it contains, however, many objects of the sixteenth and seventeenth centuries, arms, armor and cannon, of the days of European as well as of native wars. Among other curious

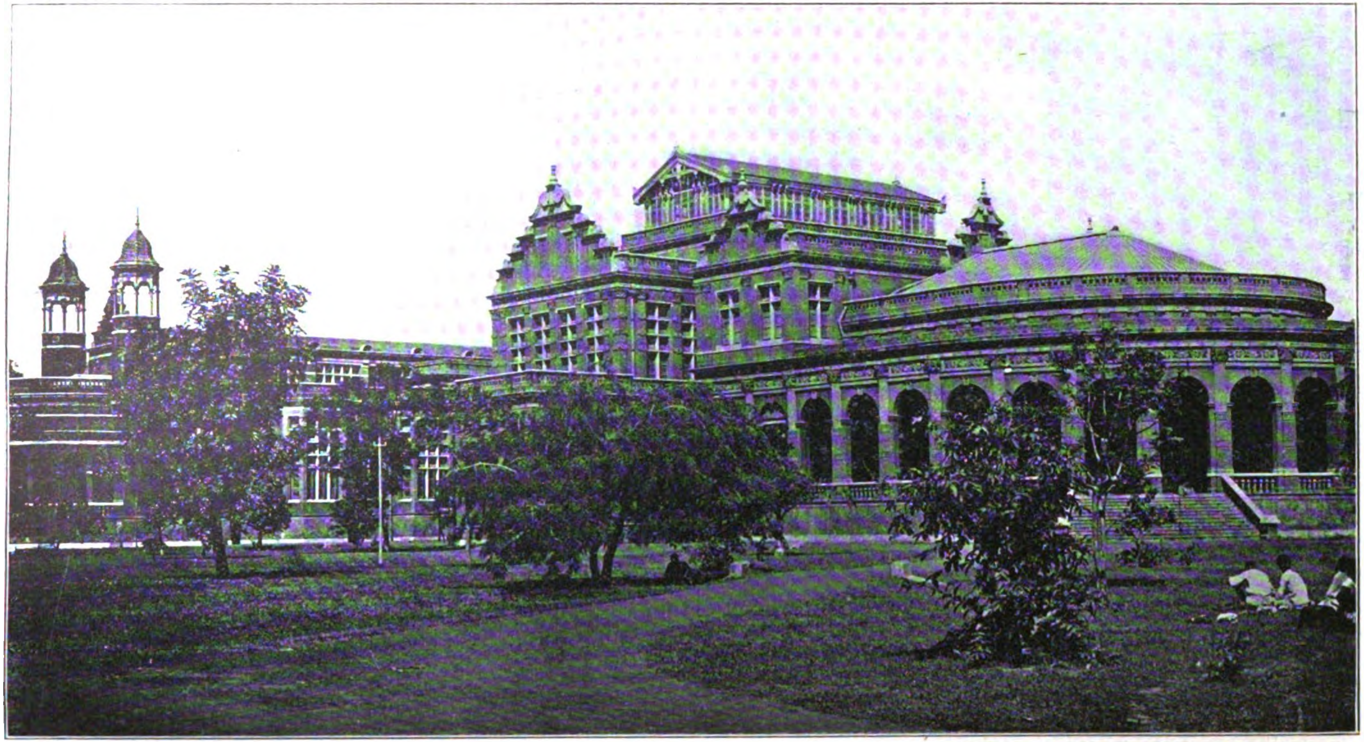

FIG. 4. MADRAS. MUSEUM BUILDING.

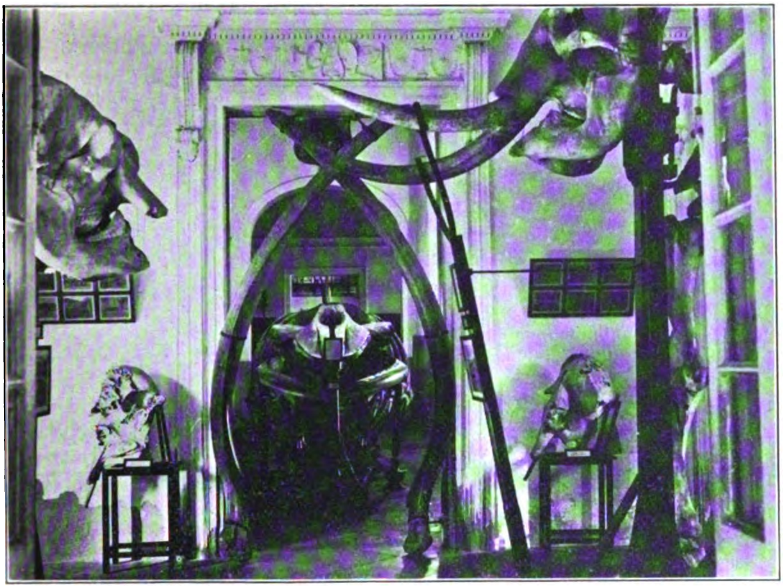

FIG. 5. MADRAS. VIEW IN ONE OF THE NATURAL HISTORY GALLERIES.

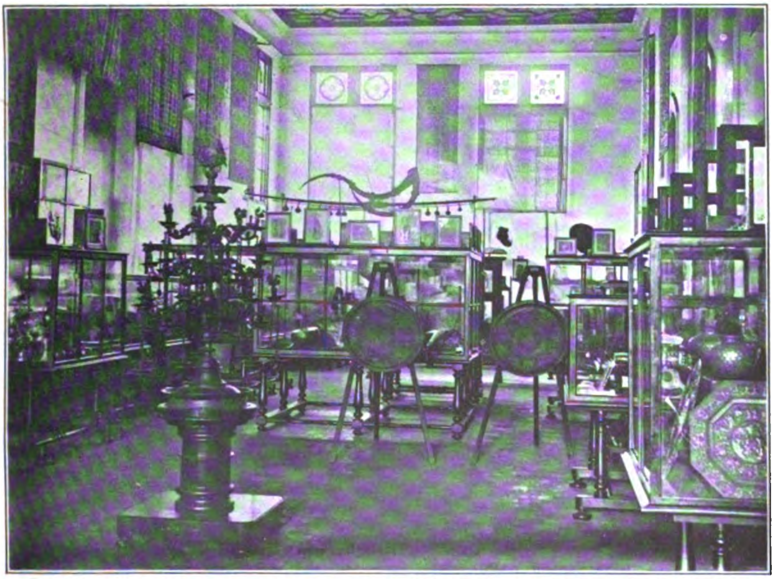

FIG. 6. MADRAS. GALLERY OF METAL WORK.

relics is a large swinging-post terminating in an elephant head, probably unique, which in a remote village was used up to relatively recent times for human sacrifices. The art objects are represented in great variety and are attractively exhibited, textiles, pottery, wood and metal work, musical instruments, drawings. One recalls especially the suite of pictured cotton curtains for which Madras has long been noted; also the beautiful repoussé work in precious metals (Fig. 6). The museum is distinctly one of the most successful in India. Its director is the zoologist, Dr. Edgar Thurston.

Calcutta

The museum of Calcutta is far and away the most imposing of Asiatic museums, representing, as it does, the government of India in the imperial capital. Its buildings, Fig. 7, are the most extensive and its collections the most important. In this region, moreover, it is the oldest, for it preserves the collections of the Asiatic Society of Bengal, founded in 1784.

The success of the museum, it may be remarked, has been due in no small degree to its tradition of selecting directors eminent both as scientists and as executives. It was to Mr. Bly, an early curator of the Asiatic society (1842 to 1862), a voluminous correspondent of Darwin, by the way, that the credit belongs for securing governmental assistance in erecting the museum's first building. His successor was John Anderson, who remained in charge until 1886. And his, in turn, was Dr. Wood Mason, 1886 to 1893. And from that time to the present, the director has been Major A. Alcock, widely known for his researches on the deep-sea fauna of the Bay of Bengal.

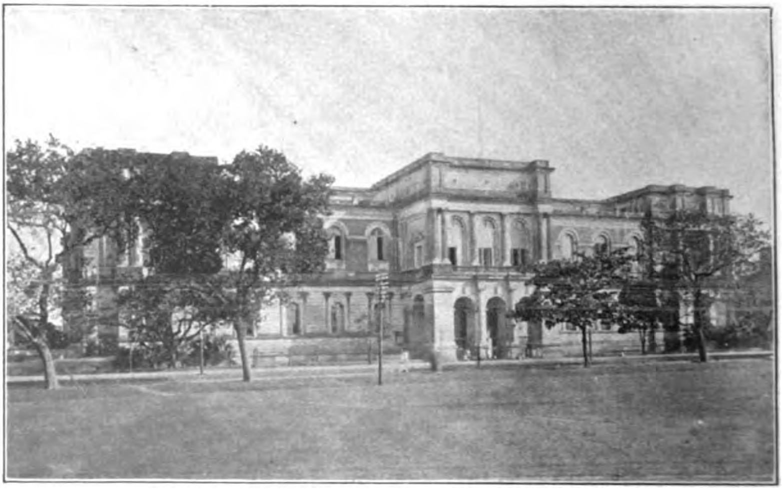

FIG. 7. CALCUTTA. THE INDIAN MUSEUM. Front view. From Chowringhee.

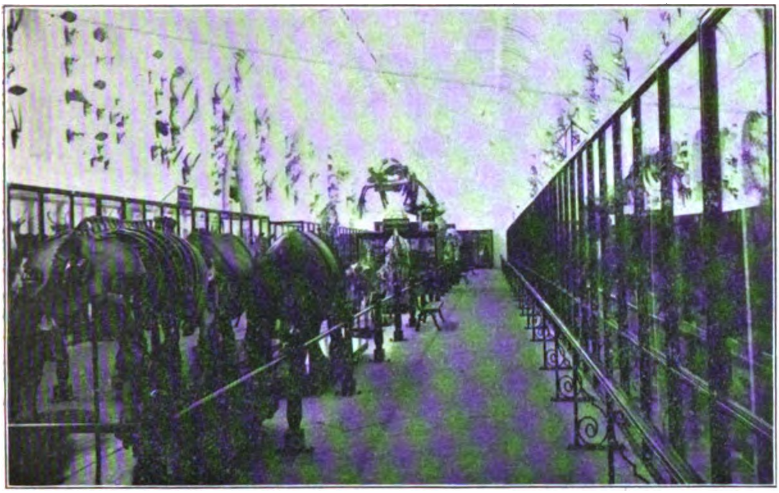

FIG. 8. CALCUTTA. HALL OF INDIAN MAMMALS.

At the time of the opening of the new museum (about 1890) the collections of the Asiatic Society were transferred to the British government. They comprised principally three classes of objects, zoological, ethnological and archeological, the last of unique importance. They include the antiquities secured by Colonel Mackenzie from the Amravati tope (1796 and 1816), and the collections of the Tytlers, Kittoe and General Cunningham. The last named investigator, one of the founders of the museum, secured for it also the objects from the Bharhut stupa. The entire collection thus contains in large measure the figured specimens in Indian archeology and it is especially rich in the finds from the neighborhood of Lucknow, Nagpore, Benares and Delhi. The ethnological cabinet is based upon the collection of Roer, whose catalogue dates from 1843. By 1882 no less than 600 crania were listed. The zoological division of the museum is based upon the Blyth collection of the Asiatic Society. As early as 1862 there were represented 600 species of mammals, 2,000 species of birds, 300 of reptiles, and 1,000 of mollusks; and since this time the zoological collection has increased vastly. Figs. 8, 9, 10.

The Calcutta museum expanded notably about two decades ago, when it incorporated two allied institutions. The first of these was the economic museum of the government of Bengal (added in 1887), whose collections are arranged in separate galleries, and the second, the collections of the geological survey, these added (about 1890) when the public museum was opened. The subsidy for the latter institutions, it may be mentioned, is separate from that of the main museum, about 40,000 rupees a year being granted by the government for their annual support. And a similar appropriation is made for the remainder of the museum.

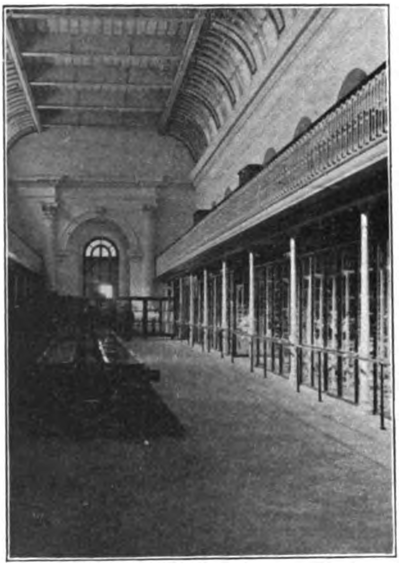

FIG. 9. CALCUTTA. PORTION OF THE BIRD HALL.

Under the present director the work of the museum has made notable advances. During the past twelve years over 100,000 specimens have been entered in the books of the museum and the new material has been extensively studied. Especially through the cruises of the *Investigator* carried out under Major Alcock's direction (Major Alcock came to India as surgeon-naturalist (1888–1892) to examine the sea-barriers of India), a wealth of marine material has been placed in the hands of specialists throughout the world. And the museum had already published many memoirs upon it—twenty-five, or thereabouts. It might be mentioned, as a sad commentary upon the relation of politics and science in India, that the well-known gallery of fishes arranged by the director, after years of labor, has recently been demolished by order of the Viceroy, Lord Curzon, who could find in Calcutta no other gallery in which to house a collection of relics of the Sepoy rebellion!

The invertebrate collections of the museum are extensive and well displayed. Particularly interesting is the entomological cabinet which includes the de Nicéville lepidoptera and the Dugeon hymenoptera, the latter comprising about 1,000 type specimens. The entomological survey undertaken by the museum is its last development, establishing in 1903 the first entomological laboratory in India, in connection with a commission of forestry. Equally important are the geological materials exhibited in the museum. Of meteors, no less than 400 falls are represented. Of ores there are many varieties, especially in manganese. In fossils there is valuable Cretaceous material, including the types of Blanford; among late acquisitions there is a wonderful specimen of *Elephas antiquus* (*namadicus*). The fossil mammals from the Sewalik Hills near Simla are also preserved in the

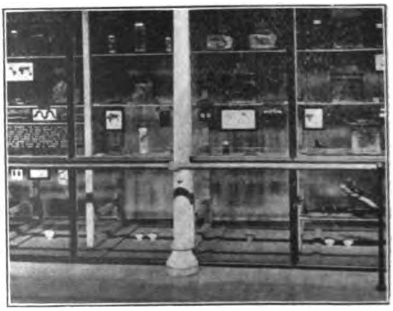

FIG. 10. CALCUTTA. A CASE IN THE REPTILE GALLERY.

gallery of paleontology, but they fail to impress a visitor who has seen the associated remains of late Tertiary mammals in other museums.

LAHORE

The museum at Lahore is known to most foreigners as the "wonder-house" of Kipling, and in front of its door stands the ancient cannon with its memories of Kim and his lama. Although intended to represent the natural sciences as well as the arts, this museum need hardly be referred to in the former regard, for its specimens are few and poorly displayed. In its materials for the study of art, however, it ranks among the foremost in the east. Its predecessor was a school of arts, founded as a memorial to the Viceroy, Lord Mayo, and carried out during the early seventies, under its first principal and curator, Mr. J. Lockwood Kipling (1875–92). The development of the present museum then came about as a result of the Victorian jubilee. A general subscription secured the necessary funds, and the corner-stone of the present building (Fig. 11) was laid by Prince Victor in February, 1890, and its collections were opened to the public two years later. The design was furnished by Mr. Lockwood Kipling in cooperation with the Indian architect Bryam Singh.

As in the majority of the Indian museums, the native style has been as closely followed as museum needs would permit, and the tall galleries and massive doorways (Fig. 14) leave pleasant impressions in the

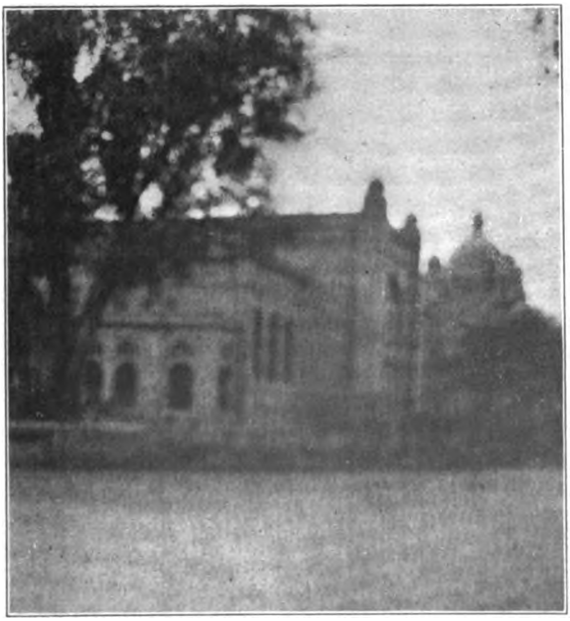

FIG. 11. LAHORE. THE MUSEUM.

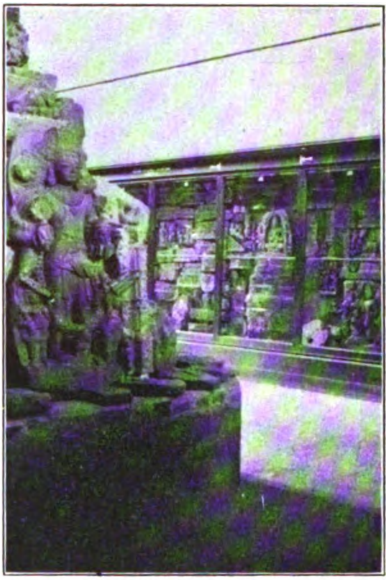

FIG. 12. LAHORE. THE HALL OF GRÆCO-BACTRIAN SCULPTURE.

visitor's mind. The exhibit space includes about 28,000 square feet and the galleries are 45 feet high. As already noted, the museum is interesting in its art exhibits, especially in its Græco-Bactrian sculptures, for these, as is well known, played a most important part in the early art of northern India. This collection, occupying a special gallery 100 feet in length (Figs. 12 and 13), was brought together in the northwest provinces during the early seventies, and is unique. To be mentioned also are the collections of carved wood, musical instruments, Hindu portraits, including a series of the Singh, Hindu drawings, many Afghan documents, and technical exhibits decidedly modern in museum technique, illustrating, for example, the arts of the Punjaub, glass making, lac turning, leather work, etc. In connection with these there are models of local industries cleverly carried out in terra-cotta by native artists. One may mention also a remarkable series of Madras curtains elaborately stamped with religious ceremonies and personages. The present administration of the art school and museum is in the hands of Mr. Percy Brown, artist and archeologist, well known for his studies on Græco-Bactrian art. The museum is now affiliated with the Asiatic Society of Bengal, with the Geological Survey of India and with the Forestry Commission. As an echo of Indian social conditions one hears that the museum has been opened one day a month for Hindu women, women attendants then taking charge of the galleries. The museum is popular, and the attendance averages over 1,000 a day.

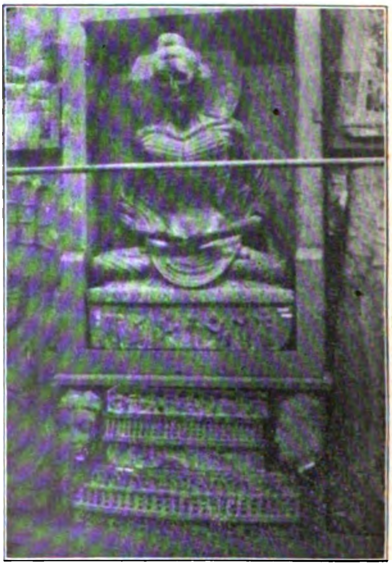

FIG. 13. LAHORE. DETAIL IN HALL OF SCULPTURE.

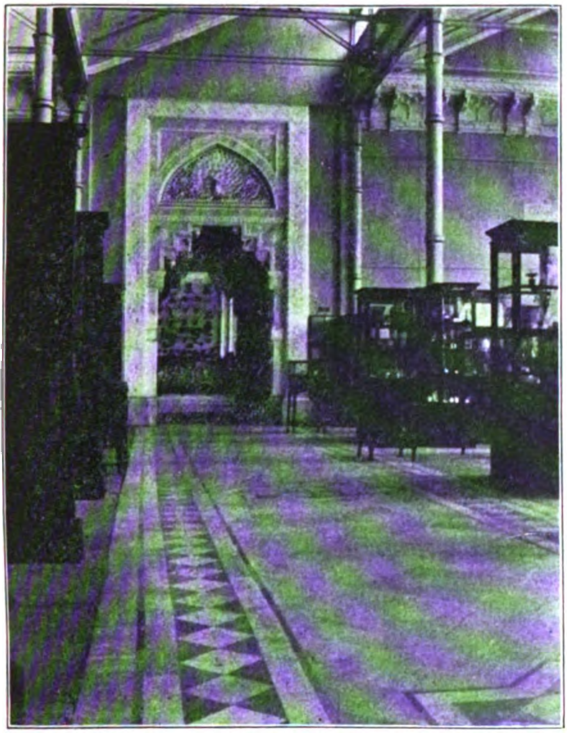

FIG. 14. LAHORE. THE HALL OF NATIVE ARTS.

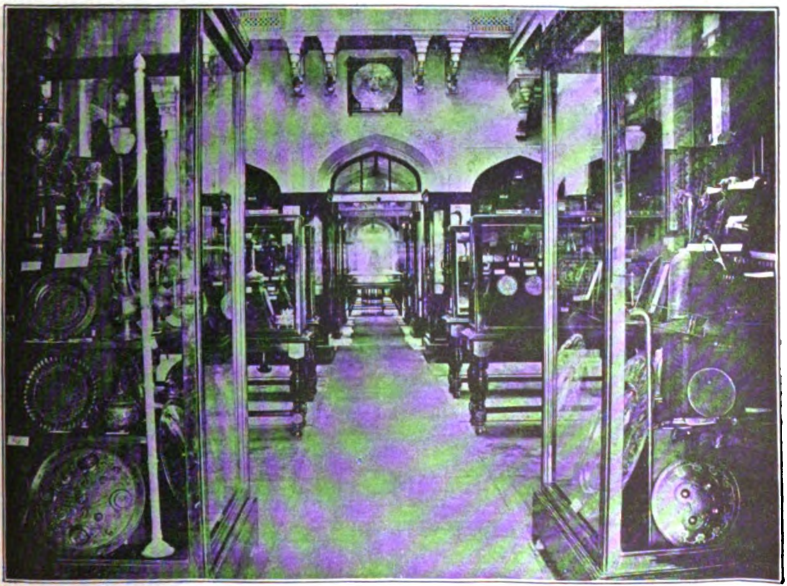

FIG. 15 JAIPUR. HALL OF METAL WORK.

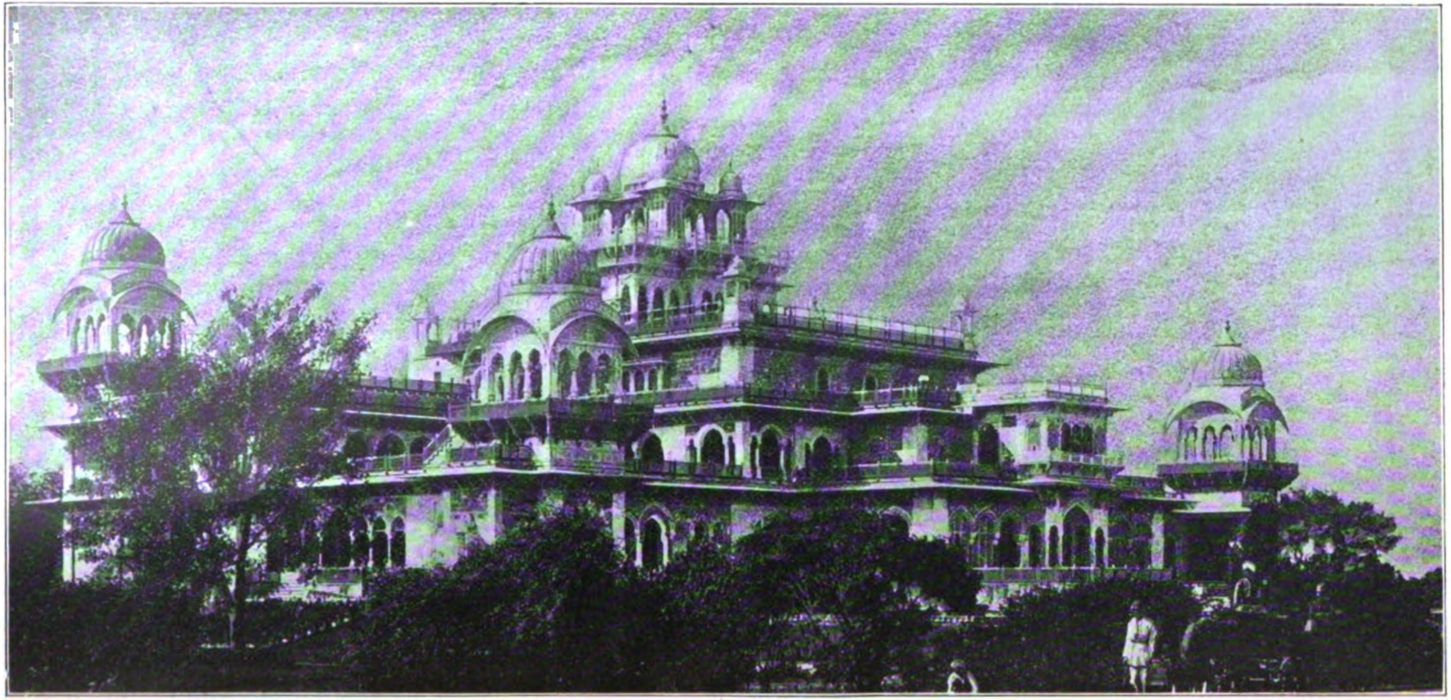

FIG. 16. JAIPUR. THE MUSEUM.

JAIPUR

Jaipur may be mentioned, finally, as furnishing the best type of a museum supported by a native prince—in the present case by the reigning maharajah, Sir Sawdi Madho Singh. It is an imposing monument to this ruler's modernness, and it has already borne interesting fruit in developing and bettering the many art-industries of Jaipur.

The building is by no means a small one—at least two hundred feet in length. It stands in the public gardens, an elaborate structure in Indo-Saracenic style, with shaded balconies and corridors, and with numerous courtyards cooled by plants and fountains, Fig. 16. Its scientific collection is small, limited to models and specimens of minor interest. But in modern and semi-modern art objects, in metal, stone, wood or textile, the present museum is, I believe, unsurpassed. Especially beautiful are the examples of metal work, Fig. 15, many of which are the family treasures of the maharajah—gun-metal and silver bidri work, damaskeens from Kashmir, silver repoussé from Trichinopoly and Ceylon, articulated objects in silver from Bengal, silver figures from Mathura, enamels in gold from Jaipur, in silver from Multan, brasses numberless, and a bewildering series of jewelry from all parts of India. Nowhere can one receive a more illuminating impression of the decorative possibilities in native art. An excellent reference, by the way, is the beautifully illustrated handbook of the museum prepared by its honorary secretary, Colonel Hendley (1895).

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ACCIDENTAL RESEMBLANCES AMONG ANIMALS. A CHAPTER IN UN-NATURAL HISTORY

By Professor BASHFORD DEAN
COLUMBIA UNIVERSITY

[Reprinted from The Popular Science Monthly, Vol. LXXII, April, 1908]

[Reprinted from THE POPULAR SCIENCE MONTHLY, April, 1908.]

ACCIDENTAL RESEMBLANCES AMONG ANIMALS. A CHAPTER IN UN-NATURAL HISTORY

BY PROFESSOR BASHFORD DEAN
COLUMBIA UNIVERSITY

THE naturalist of to-day is perhaps unduly saturated with the belief that animals and plants adapt themselves to their surroundings. He has seen so many and such admirable examples of this, and in every field of his work, that he is apt to conclude that the principle of adaptation can be called upon to explain phenomena which when critically considered may prove to be not adaptive at all. In the familiar case of an insect whose colors suggest lichen-covered bark, or a dead leaf, or a flower, we have come to conclude, since we have seen many examples of demonstrated utility, that the resemblance is significant, that it protects the insect against its enemies and that it has been the outcome of a series of evolutional changes which have made the protective coloration more and more complete. We have even reached a point, some of us at least, where we neglect to scrutinize the evidence that the creature in question frequented the kind of bark, leaf or flower which it resembles, or that, if it did, it was thereby protected so completely as to ensure its survival. We have reached the point, to make this attitude clear, when we hold up before our students a butterfly mounted on a twig and point out the marvelous "protective" resemblance between the butterfly and the neighboring pressed leaves, without suspecting that the leaves belonged to a beech tree "made in Germany," and that the butterfly came from the East Indies!

So also is our attitude a lax one in the case of animals which resemble other animals and are thereby protected, like moths which resemble wasps, flies which can be mistaken for bees, butterflies which are similar to butterflies known to be rejected by birds, etc. For we have seen so many instances of undoubted mimicry that we are apt to accept resemblances as of this type, even if they have not been experimentally demonstrated. That such accurate resemblances, on the other d, could occur even in animals which live side by side *and yet mean hing,* would be something of a heresy to many evolutionists. Yet m inclined to believe that this is a fact—although to prove this in crete instances would be at the moment difficult. However, it can, hink, be established indirectly and by striking analogies. For if re occur among animals numerous resemblances which mean noth-, we may justly be skeptical of other resemblances—unless their e can be experimentally proven.

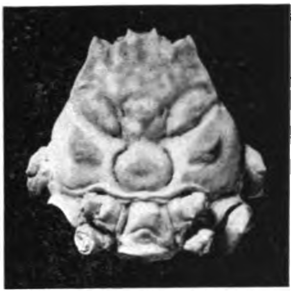

FIG. 1. CARAPACE OF A JAPANESE CRAB. *Dorippe* picturing in relief an oriental face.

In point of fact, if we sift out the cases in which mimicry and protective coloration have been demonstrated beyond question, we find that their number is by no means as large as we at first assume. And of the remaining cases, probable, or imperfectly proven, we should, in fairness, leave open the possibility that what seems protectively colored or mimetic resemblance might in the end turn out to be accidental and meaningless. And in the present notice it may be interesting to refer to these meaningless resemblances in order to show both that they are abundant, and that they are excessively complicated—in certain cases, even more complicated than those which are commonly regarded as typical, if not brilliant instances of protective or mimetic adaptation.

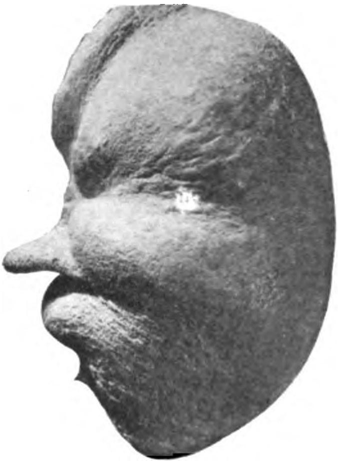

FIG. 2. WHALE'S "EAR-BONE" which in profile suggests the face of a Scandinavian fisherman.

As an example of a meaningless resemblance let us first refer to the Taira-crab, a *Dorippe,* Fig. 1, on whose back a human face appears strikingly portrayed. This crab occurs rather abundantly in a region of the Japanese coast where many centuries ago a great naval battle took place: and *it was only after this time,* local Buddhistic tradition states, *that a face of a Taira warrior appeared on each carapace,* as tangible evidence that the souls of the dead migrated into the bodies of these lower animals![1] Now, the resemblance in this case is developed to an almost uncanny degree; the face, first of all, is clearly oriental—even more Chinese or Corean in type than modern Japanese, but from this very fact the more singular, since at that time but few

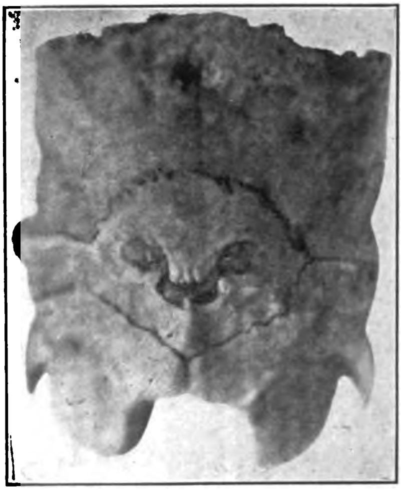

FIG. 3. OCCIPUT OF GOAT'S SKULL, showing face of Hanuman monkey.

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[1] A.D. 1184, at Dan-no-ura, the Taira clan was exterminated by the rival Minamoto headed by Prince Yoshitsuné.

Ainos had been absorbed into the Japanese race, and its physical features were therefore, on historical evidence, more strongly continental. The face, in the second place, is that of a drowned man: it is horridly infiltrated, the nose swollen and the mouth widely opened. In such a case the complicated nature of the meaningless resemblance can hardly be overestimated. For we have in it, as will be seen, a series of resemblances which are added one to the other, from the general to the specific, in somewhat the following way: human face (in itself, of course, a very complicated structure): male: young: oriental: primitive Japanese: drowned.

A second meaningless resemblance is shown, Fig. 2, in a whale's "earbone" which was found on a beach in Norway: it portrays in half relief a Scandinavian face of low caste, and with almost absurd accuracy—with rounded cheek-bones, flattened nose-bridge, small upper lip and receding jaw.

In both of these cases there is an extraordinary meaningless correspondence between the resembling objects and the especial locality in which they occur. And this condition occurs with amusing frequency.

A case in point occurs in the skull of a goat, Fig. 3, picked up in Agra, which shows on its supra-occiput the face of the common monkey of the locality, the Hanuman (*Presbytes entellus*), for it shows (with a slight tax on the imagination) the front view of this monkey's forwardly directed beard, cheek-tufts and brow-hair, and these, too, in light tone against the dark-colored face.

Another possible case is that of the squash seeds, Fig. 4, which in drying acquire irregular depressions on their surface, and thus produce the effect of idiographs. They are said to have come originally from Japan, but in any event so perfect are the "characters" that I have known a Japanese scholar to puzzle over them for several minutes in his effort to read them!

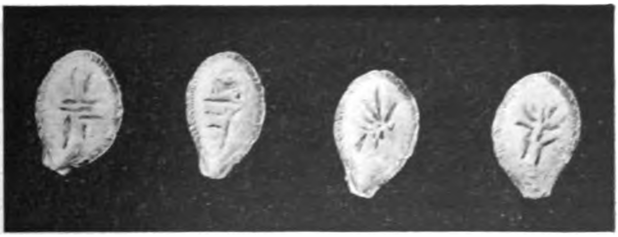

Fig .4. Squash Seeds Picturing Ideographs.

A somewhat analogous instance, Japanese (noted by my friend, Dr. Yatsu), is that of the "Tokugawa fish," a small species of *Salanx*, which is said to have appeared in Yedo (Tokyo) shortly after the last dynasty of regents made their seat there. This fish is curious in that its head bears the badge of the Tokugawa family, the three *Asarum* leaves conjoined. This effect is produced by the lobes of the brain, which can be clearly seen through the transparent headroof.

An example which pictures a human face almost as strikingly as in the Taira crab is seen in the chrysalis of the butterfly, *Feniseca tarquinius*, Fig. 5.[2] For here the resemblance is developed in remarkable detail, with forehead wrinkles, eyebrows and lids, aquiline nose, thin determined lips and straight mouth—all in this case as palpably Caucasian as the Taira face was proto-Japanese. If the present photograph had been taken from a larial mask of Tarquin himself, it could hardly appear more human!

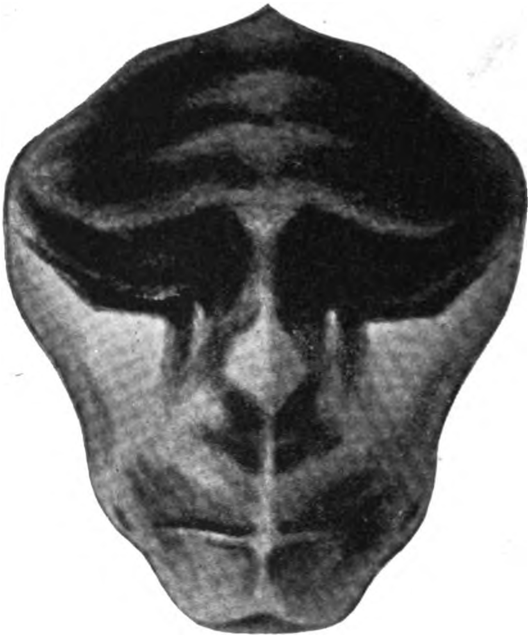

FIG. 5. PUPA OF THE BUTTERFLY, *Feniseca tarquineus*. (Cut loaned from *Entomological News*, through the kindness of its editor, Dr. Skinner.)

A second pupa-portrait is given in Fig. 6, in the case of *Spalgis S-signata* Hol. In this instance not only are the characters of Feniseca paralleled, but there appear hair (frankly not a vast chevalure) on the "head," pupil in the "eyes," and the general appearance in grotesque of the head of a chimpanzee. Not remarkable, therefore, that the habitat of the "mimicking" insect is West Africa!

A third pupa portrait, Fig. 7, again a Feniseca,[3] but I do not know of what species, is taken from a photograph of a dried specimen. It has the face-like appearance, and suggests amusingly the restoration of the *Brontosaurus,* in the American Museum.

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[2] For the permission to use this figure, and the loan of the cut itself, we are greatly indebted to Dr. Skinner, the editor of the *Entomological News*.

[3] For this I am indebted to Professor Wheeler.

Still another meaningless resemblance is in the death's head moth, *Acherontia atropos,* which shows a "remarkably faithful delineation of a skull and bones upon the back of the thorax." And in allied species the skull is even more sharply pictured—in *A. lachesis,* for example, where it appears in minature size.

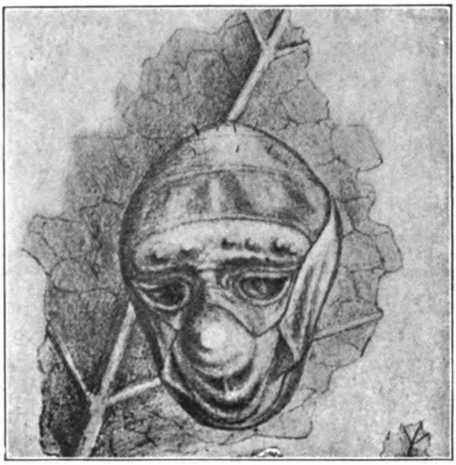

FIG. 6. PUPA OF *Spalgis,* showing "monkey face." (From figure published, 1892, in *Psyche.*)

A less familiar case, and as obviously meaningless, is the resemblance to a cuttle fish, which one finds in the end view of the larva of the crane-fly, *Tipula abdominalis,* Fig. 8. This appearance might conceivably inspire a wholesome dread among some marine creatures—but the fact remains that the present larva lives in wet rotten wood (or under ground) where an octopus-like resemblance could not benefit it. Indeed among insects one may find numerous instances of accidental resemblances. Some pupæ we have already referred to. Others, bombycids, for example, suggest mummy cases, the region of wings, antennæ and tongue, picturing both in form and proportions the Egyptian head-gear and beard. It is improbable, to say the least, that the Egyptians arrayed their dead after the fashion of a pupa to encourage a teleological analogy, for one reason, since the headdress and beard were displayed in a similar fashion during the lifetime of the individual. Striking, too, are pictures which one sometimes finds on the wings of butterflies—among these, as Mr. Beutenmüller showed me, are the heads of French poodles, which appear *en silhouette* on the wings of the orange-colored butterfly, *Colias* (*cæsonia* and *eurydice*). And on the hind wings of the ragged butterflies (*Grapta*), as every one knows, appear commas and semicolons printed in silver upon an otherwise dull-colored wing. In the group of bugs (Hemiptera) one recalls the initial W, which occurs in certain cicadas, and there is the interesting case of the tree-hopper, *Membracis binotata,* to which Professor Wheeler drew my attention. This tree-hopper and its young

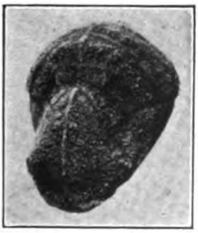

FIG. 7. PUPA OF *Fenisseca* SP., showing "face."

represent amazingly "a family of tiny birds with long necks and swelling breasts and dropping tails, verily like an autumn brood of bob-whites" (W. H. Gibson), Fig. 9. Had they been twenty times their present size they might have run the risk of being described as mimics!

Among other resemblances of this nature one recalls the spectacles which appear on the neck of the cobra. Then there are the insect, monkey and human figures in orchids and in various other plants, pictured in flowers, parts of flowers and in fruit. The last sometimes give striking and grotesque forms, as in the case of our common garden snap-dragon, Antirrhinum. Here, Fig. 10, the seed pods look like diminutive human heads which are arranged on the stalk in a way which suggests the poles-of-skulls, or "medicine" ornaments of certain savages. Peculiarly perfect is this resemblance, for there are pictured not merely the cranium and face, but the dried and weathered portions of scalp, eyelids, lips, as well also as temporal sutures. The color of these seed pods, furthermore, is strikingly like that of mummied heads. Meaningless resemblances occur also in various bones, as in the case of the goat skull or the "ear-bone" noted above. Thus, as Hugh Miller long ago discovered, there is a curious human figure in the cranium of a Devonian fish, and the rabbit, even when "dead and turned to dust" is not free from its arch-enemy, for its sphenoid (Fig. 6) pictures the head of a fox so cunningly indeed that this bone has long been used as a scarf ornament for the English hunter.

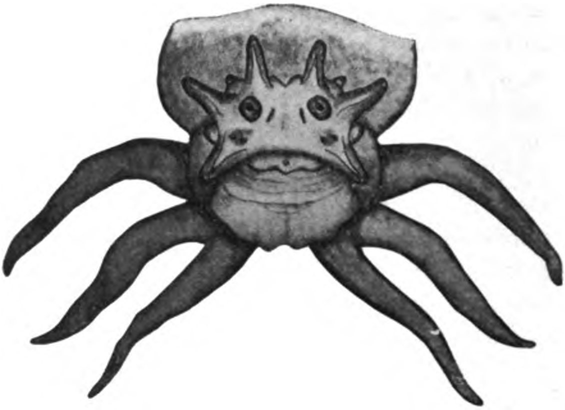

FIG. 8. "OCTOPUS" SHOWN IN HINDMOST ABDOMINAL SEGMENTS OF THE LARVAL TIPULA

Instances of this kind need hardly be multiplied. They extend on every side in the inorganic as well as the organic—from the simple cloud figures conjured by Aristophanes or the various forms of weathered rocks (like the "camel of Brignogan"), to the most curious and complicated.

In short, therefore, it is clear that if meaningless resemblances are numerous and striking, one can accept protective resemblance and mimicry only in instances which have been fully demonstrated. And we may in the meanwhile mark as doubtful numerous cases which now pass current in zoological literature. Among these would, I believe, fall the famous leaf-like butterfly, *Kallima,* which Weismann has adopted as the ne plus ultra of protective resemblance, for in the lack of adequate experimental evidence even this form may prove to be a meaningless resemblance, and not the product of selection. That it may be, and probably is, of protective value at the present time can as readily follow from an accidental resemblance which happens to turn out to be valuable as from one which has been the product of numberless selected variations. In fact, it is quite credible, it seems to me, that accidental favorable variation may have furnished the basis of many a useful resemblance—as some mutationists believe. And there are no peculiar "adaptive characters" in *Kallima* which can safely be construed as more complicated than the meaningless characters of the Taira crab. For in what way is the resemblance of a

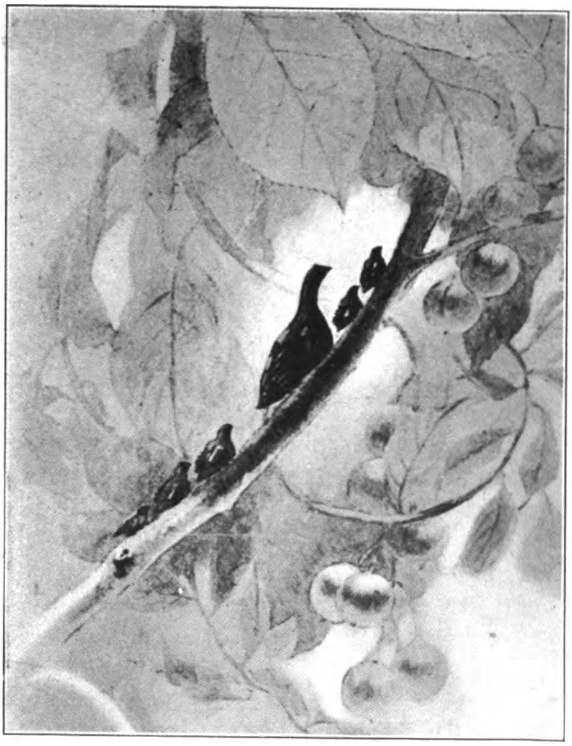

FIG. 9. TREE-HOPPERS WHOSE APPEARANCE SUGGESTS BIRDS. After Gibson in *Century.* (Cut kindly loaned by Dr. Skinner.)

butterfly with folded wings to a leaf more remarkable than the appearance of a human face on the back of a crab? For the contrast, when dissected, would give us in the one case the characters—leaf-shape, color, midrib, reversed markings (veins) on one side of midrib, concealed legs and antennæ, "petiole," and fungus-like patches, as opposed, in the case of the crab, to the equally complicated characters—human face, color, young, oriental, primitive Japanese, drowned. It is only fair to conclude, therefore, that if a meaningless variation can produce the Taira crab, it might equally well have produced *Kallima*.[4] The conclusion, indeed, that Kallima formed the apex of a series of selected changes, is, on our present evidence as to the habits of this insect, hardly different in kind from the assumption that the present perfection of the skull on the death's head moth is the result of selective changes, through whose agency this form came gradually to be avoided and thus secured immunity from, by superstitious man, an important enemy! In fact, in this case, there is actually a stronger body of evidence that the moth is avoided by man than that Kallima is overlooked by birds.

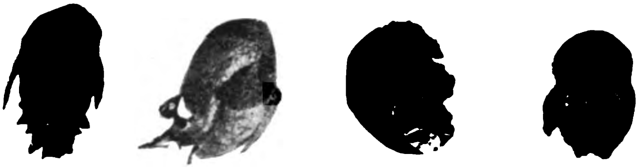

FIG. 10. FRUIT OF THE GARDEN SNAP-DRAGON, *Antirrhinum*.

In a word, it is a fair conclusion that our notions of protective resemblance and mimicry are carried in numerous instances farther than the law allows. And one does not have to go far afield for cases in point. Thus the snake's head which is pictured on the wing tip of an East Indian moth, *Attacus atlas*, does not strike one as a convincing case of mimicry, in spite of Weismann's arguments. It is true that the snake is strikingly portrayed, both in color, poise and expression, and we will readily admit that it *might* give a wholesome jolt to some enemy of the moth which happened to see it just at the right angle. But the picture in this instance is not more striking than many of the meaningless resemblances we have quoted (*e. g.*, the French poodle pictured on the wing of Colias), and I think we may reasonably demand definite experimental proof before accepting the "mimicry." In certain other instances one can not feel assured that the resemblance is of actual value to the "protected" form. As an instance of this,

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[4] In this connection, *cf.* a note in *Science*, Vol. XVI., p. 832, in which the present writer comments upon the scantiness of evidence as to the protective value of the characters of *Kallima*, and notes the appearance of this insect on and near leaves which it in no way resembled.

I recall the living *Ichthyophis,* the curious burrowing salamander, which I once had the opportunity of observing in Ceylon. This is surprisingly like a worm in many regards, yet a mimic it can not be, since it could derive no profit from the resemblance, the worm being infinitely less protected than itself. If any mimicry could exist in this case it is clearly in the opposite direction, the worm mimicking the salamander, but this possibility is precluded since the mimicking form is infinitely more plentiful than the mimicked, and, most significant, neither form is apt to expose itself in a light where the resemblance would have any value. None the less the mutual resemblance is quite striking—in shape, proportions, size, color, annulation, movements, position of vent, etc. Yet we can only interpret it as due to parallelism. And if this is the case, may not parallelism, *i. e.,* similarity in structures due to similarity in habits, not mere accidental resemblance, be taken as a further danger in interpretation.

For the rest we may query, as others have done, whether the importance of protective coloration and mimicry may not be still further diminished when we eliminate our anthropomorphic conception of the senses of the lower animals. For we may reasonably harbor the suspicion that colors and patterns, which to man seem protective, are by no means as valuable as protection against the keener and more specialized visual impressions of the lower animals. For just as "scent" perception in certain invertebrates, as in various moths, is immeasurably refined, far more so than we are in the habit of conceiving the scent-sense, so also there may have been developed a special sense for detecting the most subtle differences in color, texture, form in those animals which prey upon mimetic and protectively colored forms. Indeed, such a view is the less unreasonable when one considers the condition of the optic centers and end organs in those vertebrates, teleosts, reptiles, amphibia, birds, which have most to do with creatures in which protective coloration and mimicry is supposed to occur most abundantly. And it is not beyond the pale of possibility that the predatory forms have evolved habits in connection with sense-organs which would cause them to distinguish more promptly the protected forms than those having bright and obvious colors. It is in this direction that we have need of close observation and critical experiment.

Compliments of
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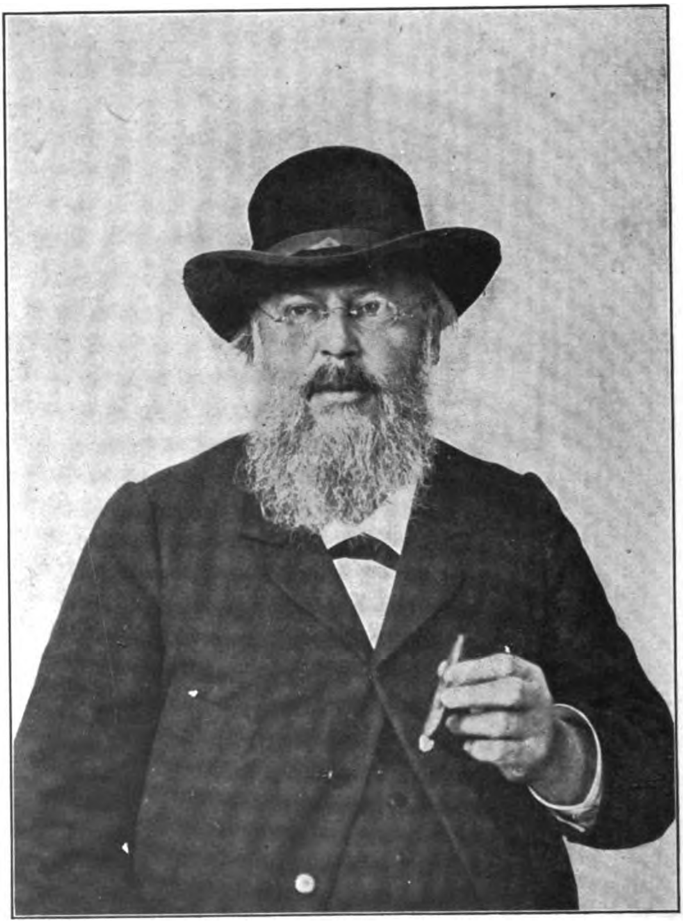
ANTON DOHRN

Reprinted from the Popular Science Monthly, January, 1910.



Anton Dohrn.

[Reprinted from The Popular Science Monthly, January, 1910.]

THE PROGRESS OF SCIENCE

ANTON DOHRN, 1840–1909

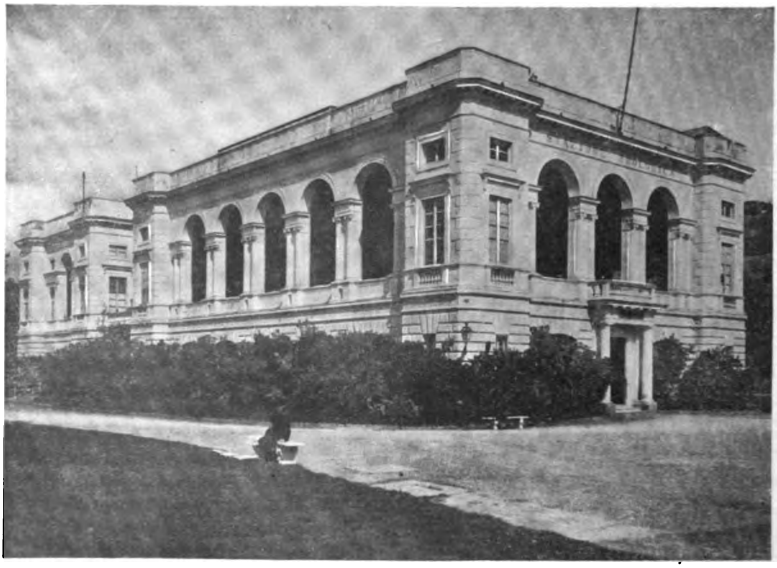
In the death of Anton Dohrn zoology mourns a veteran leader, and many zoologists feel—though some of these may not have known him personally—that they have lost a genial and helpful friend. Every one knew him directly or indirectly, and one may even say that there are but few zoologists who are not in some way or another in his debt. For he founded the great station at Naples, and fostered its activities in many directions. It is no mean test of his successful management that it is supported by the funds of many nations and of many diverse institutions.

Dohrn's monument will ever be the Stazione Zoologica: its inception was his, its upbuilding, its policy and its completion—if such a work can ever be called completed. From the time of his early studies—while indeed he was in Messina, in the sixties—he had ever before him the vision of a completed zoological station, an international one, vast in size, splendid in equipment. And with prophetic eye he selected Naples as the field of his life-work. He soon found that his project was not an easy one to carry out, especially in days when sea-side laboratories were rare and obscure, and when indeed zoology had hardly come to its own in the scheme of sciences. But Dohrn surmounted the difficulties, scientific, political and financial. In the last regard, when the Academy of Berlin failed to endorse his project, he showed to friends and enemies his faith in his convictions by putting his personal funds, almost all of them, into the melting pot. In the end his arguments were so convincing that the German government granted him a handsome annual subsidy, and insured the success of his undertaking.

Dohrn's history can here be given only in the briefest lines. He was born in 1840, the son of a North German Fabrikbesitzer of scientific tastes. He became a student of Schnell in Jena, devoting himself especially to the study of the arthropods. He was appointed privat-docent; then he traveled, theorized and wrote, but he taught little; apparently he did not care for the class-room, and even at the end he could point to but few whom he had directly trained. At the outbreak of the war of 1870, Dohrn became a soldier and fought through the campaign; then he returned to his great plan of the stazione and his struggles in its behalf. The opening of the first building was in 1874, the publications (Mittheilungen and Memoirs) of the station began in 1879, the second building was completed in 1890, the third building (for physiology) in 1907. Through all these years he continued his difficult researches, publishing his results in a series of memoirs. From the first to the last Dohrn showed a rare many-sidedness; to many he was ever the genial friend, to a few the explosive and repentant enemy; at one moment he was the tactful executive, at another the amateur of music and art, at all times the idealist and the profound and conscientious scholar, ever ready (*too* ready some said) to accept the evidence of facts and to change his scientific views. He had qualities, all in all, which made him a personage of first magnitude in the annals of zoology.

Dohrn's activities in research could readily be made the theme of a volume. For he was a tireless worker and his publications touch many of the most important problems of his day. His earlier years were spent in the study of the embryology of the arthropods (1858–81): of this period is to be mentioned his beautiful monograph on the pantopods. In 1875 appeared his paper "On the Origin of the Vertebrata and on the Principle of the Change of Function"; it was a small brochure, but it touched with a master's hand some of the great problems of its day. This paper Brooks declared should be read by every one of his pupils before he would give him his doctorate—this in spite of Brooks's lack of sympathy with the tenets which Dohrn had laid down. It was this paper which paved his way for researches which were to extend over a third of a century. And one may follow the development of the subject—and of Dohrn himself—in a series of twenty-five voluminous memoirs.

It was the "momentous problem of the beginnings of the back-boned animals" which Dohrn sought to solve. And upon this matter his writings are encyclopedic. Vertebrates were to him descendants of chætopod worms; their typical organs did not arise *de novo* but as transformations of organs having a different function; animals of simple structures were not as often primitive as Haeckel, for example, would teach, but were frequently degenerate; Amphioxus and Ascidians were not in the line of descent of the higher vertebrates, nor were lampreys—the latter were rather degenerate bony-fishes. In his early papers his readers are carried along on the crest of a splendid wave of enthusiasm. "The problem is solved, . . . all but solved, . . . soon to be solved." But this stage of conviction comes to pass darkly into the background, new difficulties keep appearing, and in later papers one hardly realizes the genetic bearing of the data which Dohrn is bringing together. The method of the paper of 1875, which was essentially deductive, gradually gave place to an elaborate inductive method; separate organs of the vertebrata are studied in turn, especially in the head region, and the difficulties are traced gradually into finer and finer ramifications, until in the end he deals with what appears to be purely the puzzle of nerve histogenesis. For Dohrn would not admit that the head problem in the vertebrate was not to be solved with the present materials or by the aid of the embryo-



THE NAPLES ZOOLOGICAL STATION.

logical method; and one feels that he kept hoping against hope that some clue would yet be found to lead him triumphantly out of his labyrinth of difficulties. So he held fast to his plan of research, undismayed when his fellow workers deserted him. "The problem is difficult, not dead," he is said to have declared, when others entered some new and attractive field—"and it is in the difficulties of an old problem that one learns, not in beginning a new one."

Dohrn suffered, there can be no doubt, in noticing that as time went on "the problems of the head" attracted fewer workers. But such a man must have realized, none the less, that this was an inevitable result when new lines of investigation are suddenly developed and when the number of investigators available for all fields is small. And in his heart he must have felt that his theme would always be given a high place, even by those to whom it became "unfashionable." On the other hand if there was no general sympathy for his embryological work there was certainly no lack of appreciation of his work for the Naples station. He lived to see it in the position which he had planned for it, and he took keen satisfaction in seeing his son Reinhart installed as its executive. So he may well have felt in the end, as the solace of his long illness, that his work had been well done.

[B. D.]

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